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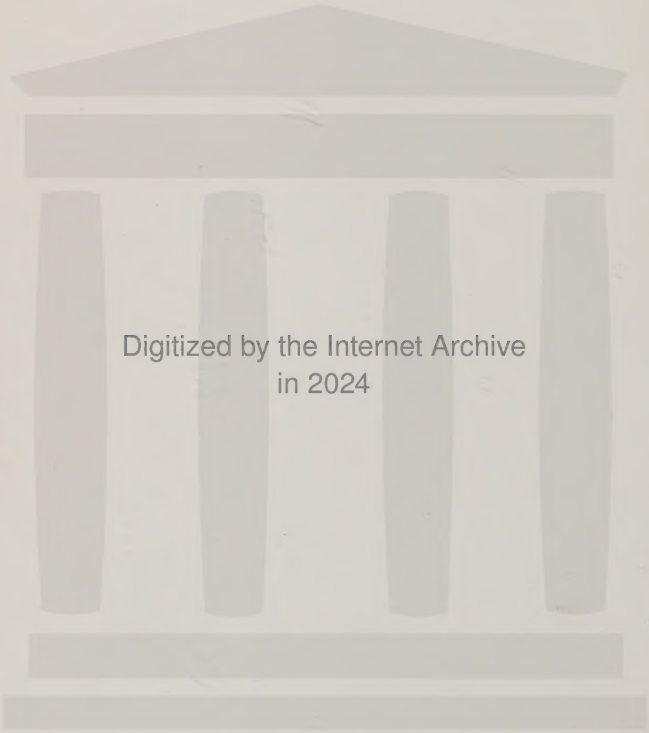
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A MANUAL OF THE COMMON INVERTEBRATE ANIMALS

EXCLUSIVE OF INSECTS

By

HENRY SHERRING PRATT, PH.D.

Professor of Biology in Haverford College and Instructor in Comparative Anatomy in the Marine Biological Laboratory at Cold Spring Harbor, Long Island

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TO THE MEMORY OF

Rudolf Leuckart

PREFACE

This manual has been written to supply the need which has been felt in this country for a long time of a book containing descriptions of the common invertebrate animals, by means of which their names and affinities can be determined. Excellent general manuals with analytical keys for the identification of the common insects already exist, but a person wishing to identify animals belonging to most of the other invertebrate groups must usually have recourse to technical papers and treatises which are for the most part inaccessible except to specialists. The book is intended more particularly for use in the eastern and central portions of the United States and Canada, and the endeavor has been made to include in it most of the common invertebrates except insects occurring in this region. In addition to these, representative species occurring in the western states and on the Pacific slope are included, as are also other species to which some special interest attaches and which are found in other parts of the world. Animals which inhabit the deep sea have not been included except in special cases where they are representative of their particular groups.

The general plan of the book is similar to that of Leunis' *Zoologie,* a standard German work which has for two generations supplied the need of a general synopsis of animals in Europe, and has been extensively used elsewhere throughout the world. As in that work, the analytical tables and descriptions of species of each of the larger groups of animals are preceded by a morphological description of the group together with some account of the habits and distribution of the animals. In these descriptions all the technical terms appearing in the tables are explained. References to the principal authorities upon which the descriptions are based are given in footnotes, as are also references to important treatises and monographs which have appeared on the animals described.

A knowledge of the historical basis of zoological names adds greatly to their significance and the author has consequently given a history of the nomenclature of each of the larger subdivisions of the animal kingdom in connection with the morphological description of it. A history of the general development of the system of classification since the publication of the tenth edition of Linnæus' *Systema Naturae* and a brief survey of the progress of zoological studies in America are added in the Introduction.

An important object aimed at in these historical notes is to give the student of American animals a background for his knowledge of zoological names. In order to attain this object still more fully, brief biographical notices of the authors of these names, in so far as they appear in this work, have been introduced at the end of the book.

In the choice of the scientific names of the animals described the author has endeavored to follow the best usage. He has usually conformed to the laws of priority established by the International Commission of Nomenclature, and has adopted the rulings of the Commission where such have been made. In a few cases, however, these laws have been disregarded, as, for instance, in the case of *Amœba, Holothuria,* and *Physalia,* and for the reason that it seems probable that in such cases the scientific names of the animals which are now in common use will by common consent be retained. The author has no desire to be an innovator in this book in the use of zoological names, but wishes only to use those which will probably in the future be the names of the animals described.

The name of the author of each species and genus follows the first mention of it in the descriptions, as is customary, and in those cases in which the author originally placed his species in some other genus than the one here employed, his name is in parentheses. Wherever an author's name appears more than once in the same genus it is usually abbreviated after the first occurrence. No other abbreviations occur in the text except in the case of Linnæus. In all cases where his name appears as the author of a generic or specific name it is abbreviated to "L."

The illustrations which have been introduced have been copied mostly from textbooks, special treatises, and monographs, for the use of which hearty thanks are here extended to their authors, whose names appear in parentheses after the titles of the figures. Thanks are also due to the following publishers for permission to make these copies: Doubleday, Page & Company, Gustav Fischer, Ginn & Company, Henry Holt & Company, The Macmillan Company, and The Whitaker & Ray-Wiggin Company.

In compiling this book the author has utilized every source of information within his reach and is consequently under obligations to very many people and their published works. His personal obligation to all those friends who have given valuable advice and assistance, often at the expenditure of much time and labor, is very great indeed. The following are those to whom he feels a special indebtedness: Mr. Nathan Banks, Dr. H. L. Clark, Prof. W. R. Coe, Dr. C. B. Davenport, Prof. J. H. Gerould, Prof. L. von Graff, Prof. C. W. Hargitt, Prof. G. T. Hargitt, Prof. J. S. Kingsley, Prof. R. von Lendenfeld (deceased), Prof. A. Looss, Dr. M. M. Metcalf, Prof. E. L. Mark, Prof. S. O. Mast, Prof. J. P. Moore, Dr. T. Odhner, Dr. A. E. Ortmann, Prof. R. C. Osburn, Dr. H. A. Pilsbry, Prof. A. A.

Schaeffer, Mr. E. L. Shaffer, Dr. C. W. Stiles, Dr. F. B. Sumner, Prof. A. L. Treadwell, Dr. T. W. Vaughan, Prof. D. D. Whitney, Prof. H. H. Wilder, Prof. S. R. Williams, Prof. H. V. Wilson, and Prof. R. H. Wolcott.

The author wishes to thank Prof. J. P. Givler of Southwestern College for assistance in revising the proof sheets, he having read a large part of the text and made many corrections and useful suggestions. He also wishes to acknowledge his indebtedness to Prof. Ludwig von Graff of the University of Graz, Austria, who extended to him the use of his laboratories and extensive library during a residence of two semesters in that city, and whose unfailing courtesy and kindness will ever be gratefully remembered. His greatest obligation, however, in preparing this work is to Dr. Charles B. Davenport of Cold Spring Harbor, Long Island, at whose suggestion it was undertaken in the first place, and without whose constant cooperation from year to year during its progress it would not have been completed.

H. S. P.

Haverford, Penn.

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INTRODUCTION

1. *The Linnæan system of classifying animals.*—The foundation of the modern system of classifying animals was laid by Carolus Linnæus in the tenth edition of his *Systema Naturae,* published in 1758. In this epoch-making work he first applied his fully developed binomial method of classification to the animal kingdom and arranged all the animals then known to science according to its rules into classes. orders, genera, and species.

The essential feature of this system and that which was new at the time was the giving of two names to each species of animals, instead of one, or several, one of which was the specific name and the other the name of the next higher subdivision in the classification, the genus. The other important features were the precisions of the terminology employed, which enables the author to characterize a species in a few words, and the natural arrangement of the classification in which the position of each species indicates the degree of its genetic relationship to all the others.

It is true that predecessors of Linnæus had anticipated many features of his system. The idea of a species was already well fixed before his time, and efforts were made to characterize those then known and the new ones which were constantly being discovered. But the names given were often complex and cumbersome and no uniformity existed between the systems of terminology of different authors. Also the custom of giving two or more Latin names to a species was frequently in vogue, but a binomial system, with the definite relation of the specific to the generic name, was new. The genus, which gives the clue to the natural affinities of the animal, was peculiarly Linnæus' invention.

Attempts had also been made by Ray and Klein and other advanced thinkers to form a system which should express the natural relationships

of animals, but such attempts were not generally understood or followed, and most authors still employed unnatural methods of arranging them. Many still followed Pliny and grouped animals according to their environmental conditions, placing those together having similar methods of life, as land animals, fresh-water animals, marine animals, flying animals, etc. Within each group the species were often arranged in alphabetical order.

Linnæus' system was very quickly accepted by the scientific world and went into universal use, and modern zoology may, in a very real sense, be said to begin with the year 1758.

So radical, however, was Linnæus' reform that neither the superiority of his system nor the simplicity of his terminology would probably have been sufficient thus to procure its instant adoption if they had not been proposed by a man of his great fame and commanding position in the world. Linnæus was considered by his contemporaries, because of his numerous and important contributions to science and his eminence as a teacher in the University of Upsala, as the greatest naturalist of all time. His importance was indicated by the phrase in vogue: *Deus creavit; Linnæus disposuit.*

The immediate acceptance of the Linnæan classification had the same effect upon the study of animals and plants in his day as that of Darwin's theory of natural selection had almost exactly one hundred years later. It gave a tremendous impetus to every branch of biological investigation and started a new era. Systematic zoology, morphology, physiology, and experimental zoology all attracted able investigators, who studied them with feverish activity. Comparative studies first became possible as now the facts of the science were for the first time arranged in something like an orderly and natural manner, and the next generation saw the rise of the sciences of comparative anatomy, paleontology, and comparative embryology, and also the first modern speculations on the blood relationships and the evolution of living things.

All these things gave a new importance to zoology and raised it from the position it had occupied of a mere annex to medicine to the dignity of an independent science.

Linnæus divided the animal kingdom into six classes: *Mammalia, Aves, Amphibia, Pisces, Insecta,* and *Vermes.* The knowledge of this last class, which included all invertebrate animals except the arthropods, was in a very confused state and one of the chief objects of the many able zoologists of the generation immediately following him was to remedy this condition. The men whose services were greatest in this direction were O. F. Müller, Lamarck, and Cuvier. In 1794 Lamarck first distinguished the vertebrates from the invertebrates and divided the Linnæan class

Vermes into the five classes of *Mollusca, Insecta, Vermes, Echinodermata,* and *Polypi.* Thus a long step was taken towards modernizing the system, and this early effort of Lamarck may be said to be the first modern classification of animals. He, in his later works, further subdivided the invertebrate types until he had ten, the fundamental idea at the basis of his classification being that the various groups of animals constitute a single ascending series which begins with the lowest and ends with the highest. This principle of the unity of the type found a wide acceptance among the naturalists of that time and was based upon the law: *Natura non facit saltum.*

In 1812 Cuvier published his subdivision of the animal kingdom into four branches or types and in 1817 his great work *Le Règne Animal,* which established the second great reform of the system, and was destined to exert an influence only second to that of Linnæus' *Systema Naturae* upon the study of animals and the development of the system. In these works Cuvier controverted the principle of the unity of type among animals and taught that, instead of one, four distinct and permanent types prevail. It was upon these four types that he based his four fundamental branches of the animal kingdom: *Vertebrata, Articulata, Mollusca* and *Zoophyta* or *Radiata.*

A comparison of this classification with that of Linnaeus will show what a tremendous advance had been made in the development of the system in the half-century separating them. The group of animals which had benefited most in this general advance was probably the *Mollusca,* which was Cuvier's special field of research. The lowest group in Cuvier's system, as in that of Linnæus, was the one about which the least was known, the *Zoophyta* or *Radiata,* being made up of several distinct and heterogeneous groups of animals which bore no near relationships to one another.

This condition led to an active investigation during the generation immediately following of all the lower animals, and a very large number of works of fundamental importance appeared. Rudolphi studied the parasitic worms, Tiedemann and L. Agassiz the anatomy and Johannes Müller the development of echinoderms, Ehrenberg the microscopic animals, Eschscholtz, Sars, and others jellyfish and polyps. The knowledge of these two latter groups was also very much extended as the result of various scientific expeditions which were sent out by the French, English, Russian, and American governments to different parts of the world, especially to the tropical oceans. Of these voyages perhaps the most interesting were that of the Russian ship *Rurik* from 1815 to 1818 in which Chamisso and Eschscholtz went as naturalists and discovered the alternation of generations of *Salpa,* that of the English ship *Beagle* between 1831

and 1835 with Darwin as naturalist, and the American expedition under Captain Wilkes between 1838 and 1842 with James Dwight Dana as the principal naturalist.

The influence of all these investigations, and also that of the newly established cellular theory of the structure of plants and animals, on the development of the zoological system, led to the third great reform of the latter. In 1845 von Siebold subdivided Cuvier's fourth type, the *Zoophyta* or *Radiata,* into three types or phyla, the *Protozoa, Zoophyta,* and *Vermes,* confining thus the term *Zoophyta* to the truly radiate animals. He also broke up Cuvier's second type *Articulata,* removing the *Annelida* to the new phylum *Vermes* and creating another new phylum for the *Crustacea, Arachnida, Myriapoda,* and *Insecta* which he called the *Arthropoda.* Two years later R. Leuckart broke up the phylum *Zoophyta,* subdividing it into the phyla *Echinodermata* and *Cœlenterata,* and emphasized the isolated position of the *Protozoa.* Milne-Edwards also formed still another new type or phylum, the *Molluscoidea,* in which he included the *Bryozoa* and *Tunicata.* The animal kingdom was thus in 1850 subdivided into eight phyla, the *Protozoa, Cœlenterata, Echinodermata, Vermes, Arthropoda, Molluscoidea, Mollusca,* and *Vertebrata,* an arrangement which is still found in many textbooks.

Darwin's *Origin of Species* was published in 1859 and the fourth and last important reform of the zoological system of classification was the direct consequence of the doctrines therein promulgated. The theory of the common descent and blood relationship of all animals which Darwin taught was at variance with Cuvier's theory of fixed types and in harmony with Lamarck's theory of the essential unity of the animal kingdom, and was first employed by Haeckel as the basis of a system of classification. In 1877 he called attention to the need of placing the entire system on an evolutionary basis and at the same time subdivided the animal kingdom into the two great groups of the *Protozoa* and the *Metazoa,* and the latter into the two great groups of the *Cœlenterata* and the *Cœlomata.* In still more recent times other authors, notably Hatschek, following Haeckel's lead, have carried the subdivision still further on the same basis. The old idea of types, however, has a very tenacious life and is still the basis of the classification of animals in most textbooks—and probably rightly so. For animals can, as a matter of fact, notwithstanding their ultimate relationships with one another, be grouped in a number of distinct types or phyla, each of which has a characteristic plan of structure. Cuvier's belief, however, that these types are fixed and isolated creations has long since been abandoned.

Very important has been the formation in recent times of the phylum, *Chordonia* or *Chordata,* which brings under the same subdivision all the

animals possessing the essential characteristics of the vertebrate type. The formation of this phylum has been due to the fundamental researches of Kowalevsky, who in 1866, 1867, and 1871 gave the first detailed and accurate descriptions of the anatomy of *Balanoglossus* and also the first detailed account of the embryology of ascidians and of *Amphioxus,* showing that these animals are related to one another and to vertebrates. The term *Chordonia* was introduced in 1874 by Haeckel to include the *Tunicata, Amphioxus,* and the *Vertebrata,* and the terms *Urochorda* and *Cephalochorda* by Lankester in 1878 for the *Tunicata* and *Amphioxus.* In 1884 Bateson, on the basis of his researches on the American form *Balanoglossus aurantiacus,* added the *Enteropneusta* to the *Chordata* and proposed the term *Hemichorda.*

The system of zoological classification was thus fixed some twenty or thirty years ago and has undergone no important changes in its larger features since. This is not true, however, of many of the subordinate and smaller of its groups, the arrangement of which changes from time to time as the knowledge of the relationships of the animals composing them increases. We find this to be especially true of certain low animals which seem to be isolated side branches of the ancestral tree, the origin of which from the main stem is still obscure.

2. *The study of animals in America.**—The earliest notices of American animals are to be found in the numerous descriptions of the country and books of travel in America which were published in Europe during the sixteenth, seventeenth, and eighteenth centuries. In Linnæus' twelfth edition over 500 species of North American animals were described, of which 78 were mammals and 260 were birds. Of the authors quoted in these descriptions perhaps the most important were Mark Catesby and Peter Kalm. The former was an Englishman who lived in the southern English colonies of America for about ten years between 1712 and 1726 and published a large illustrated work on the natural history of the region. The latter was one of Linnæus' pupils who spent the years between 1747 and 1751 in Canada and the central English colonies collecting and studying the native animals and plants for him. Linnæus also obtained much information by correspondence with American naturalists, especially Dr. Alexander Garden of Charleston, Dr. John Mitchell of Virginia, and John Bartram of Philadelphia. Thus in 1766 probably most of the larger and more conspicuous animals of the eastern part of the country were known to science, as well as many insects and other smaller ones.

* See "A Century's Progress in American Zoology," by A. S. Packard, Jr., Am. Nat. Vol. 10, p. 591, 1876. "The Beginnings of American Science," by G. B. Goode, Ann. Rep. Smiths. Inst. for 1897, Pt. 2, p. 409.

Important among the native authors of the period immediately following the Revolution were Thomas Jefferson, who has the distinction of being the only American President besides Theodore Roosevelt who has been interested in scientific pursuits, Benjamin Smith Barton, and William Bartram, the son of John, both of Philadelphia.

One of the first general works of importance on American animals was Wilson's *Ornithology* (1808-1814). Other similar works belonging to nearly the same period were Bonaparte's continuation of Wilson's *Ornithology* (1825-1833), Dr. Richard Harlan's *Fauna Americana* (1825), Dr. John D. Godman's *American Natural History* (1826-1828), which was specially devoted to Mammals, and Audubon's *Birds of North America* (1828).

During the second and third decades of the century occurred a remarkable scientific awakening in the country, an evidence of which was the publication of so many works of general interest during this time and also the foundation of a large number of scientific societies and periodicals. At the beginning of the century there were three prominent scientific societies in the country, the American Philosophical Society, which was founded in Philadelphia in 1743 by Benjamin Franklin, the American Academy of Arts and Sciences, founded in Boston in 1780 by John Adams, and the Connecticut Academy of Arts and Sciences, which was founded in New Haven in 1799. During the first quarter of the century many others were founded in various parts of the country, and in 1826 no fewer than twenty-five scientific societies were in existence, more than half of which were interested principally in natural history.

In 1812 the Philadelphia Academy of Natural Sciences was founded, and exercised an important influence from the start. The first volume of its journal appeared in 1817. Its importance in the first years of its existence was due largely to the labors of a single one of its members, Thomas Say. This talented young man joined the Academy shortly after its foundation and for twelve years, under its auspices, devoted himself exclusively to the study of the native animals, the papers he contributed to its journal and to other periodicals during this period being fundamental for the study of American mollusks, insects, and crustaceans. Another brilliant member of the Academy during this period was Charles Alexander Lesueur, a Frenchman who joined it in 1817 and, during the seven years that he was a resident of Philadelphia, published many papers in its journal on fishes, reptiles, and marine invertebrates.

Belonging to the same period was another remarkable man, Constantine Rafinesque. This brilliant and versatile man came to this country in 1802 and lived for many years in Philadelphia and in Lexington,

Kentucky. He was a pioneer botanist and zoologist and is now remembered by the large number of new species of mollusks and of fishes, as well as of plants, which he described. He is also remarkable as being the first American who clearly enunciated the principle of the transformation of species.

Philadelphia was during this period the most important scientific center of the country, but it was not the only one. The interest in natural history was widespread and every city had its public museum of natural curiosities and its scientific society. The Philadelphia Museum, which was established by Charles Wilson Peale, and the Baltimore Museum established by Rembrandt Peale were especially famous. In the South the eminent Georgian Dr. Lewis Le Conte, father of Professor Joseph Le Conte, and Stephen Elliott of Charleston were prominent as naturalists, and in the west Dr. Robert Best had founded the Western Museum in Cincinnati and given the initial impulse to those scientific activities which have ever since distinguished that city.

In New England the principal scientific interest was in geology and mineralogy. The most influential scientist was Benjamin Silliman of New Haven, a geologist and a chemist. In 1818 he founded the American Journal of Science and Art which at once became and has since remained one of the most influential in the country.

The fourth and most of the fifth decades were not a period of marked activity in the study of American animals. The remarkable development of the zoological and physiological sciences in Europe under the leadership of von Baer, Johannes Müller, Owen, Milne-Edwards and others apparently awakened little interest on this side of the Atlantic and the most important investigators were chiefly occupied with descriptions of shells and insects. In 1838, however, occurred an event important to the development of American science, for in that year the United States Exploring Expedition under Captain Wilkes started on its four years' voyage, taking as one of its naturalists James Dwight Dana.

It was in 1846 that light at length began to appear in the general darkness and the way to be prepared for the important advances of later years in the field of natural science, for in this year the Smithsonian Institution, which was to become the center of most important scientific activities, was founded under the secretaryship of Joseph Henry, and in this year also Louis Agassiz came to America.

The modern study of animals in America may be said to begin with the arrival of Agassiz on our shores. His great reputation and attractive and inspiring personality brought him at once into prominence and drew to him a large number of brilliant young men who wished to study animals under his leadership, and Cambridge and Boston soon became the most

important center of zoological investigation in the country. Agassiz elevated these studies to a much higher plane than they had occupied by placing them in close touch with European scholarship and also by broadening and extending them by the introduction of comparative embryology and physiology. He also founded and built up the first great zoological museum in the country.

The Cambridge school did not, however, contain all the zoologists in the country. In 1846 James Dwight Dana, who had become a Professor in Yale and is now remembered rather as a geologist and a mineralogist, published his *Report on the Zoophytes,* and in 1852 his *Report on the Crustacea of the Wilkes Expedition,* both epoch-making zoological works and the most extensive works of a monographic nature which up to that time had been published by an American. In 1854 appeared the remainder of his report on the zoology of this Expedition. Joseph Leidy also, in Philadelphia, was beginning his brilliant studies of parasitic worms and other small animals.

The study of shells was followed assiduously in this country during this period. Dr. A. A. Gould of Boston, who published the *Report of the Mollusks of the Wilkes Expedition* and also the *Invertebrata of Massachusetts,* Isaac Lea of Philadelphia and A. and W. G. Binney being among the most important of the many authors. The study of insects was likewise making important advances and T. W. Harris produced his *Forest Insects,* one of the earliest works on economic entomology.

The most important zoological work of the sixth, seventh, and eighth decades of the century was undoubtedly the study of the marine animals of our coast by Louis Agassiz and his pupils and followers, of whom James McCrady, William Stimpson, Theodore Lyman, Alexander Agassiz, Alpheus Hyatt, H. J. Clark, and A. E. Verrill are particularly to be mentioned. During the same period J. L. Le Conte, Samuel Scudder, C. V. Riley, and A. S. Packard were engaged in the study of insects and in laying the foundation of the influential American school of systematic and economic entomology, and J. H. Comstock established the department of entomology at Cornell which has become a leading factor in the development of the science in this country. Vertebrates were also being studied assiduously by E. D. Cope, who in the study of fishes, amphibians, reptiles, and mammals, and by S. F. Baird and Elliott Coues, who, in that of birds and mammals, all produced work of fundamental importance.

In December, 1873, Louis Agassiz died and with his death ended an important era in the history of American zoology—but only to give way to another more important. The distinctive school of zoological investigation which he founded continued to flourish, not only in Cambridge

under the leadership of Alexander Agassiz and E. L. Mark, but also in Baltimore where Louis Agassiz's pupil W. K. Brooks taught in the newly founded Johns Hopkins University. From these two centers the scientific study of animals has spread to almost all the universities and other institutions of learning of the country, and the men who have gone out from them all year by year in ever increasing numbers have maintained the high standards which Agassiz represented and have today placed American scholarship in this field in the fore rank of the world's achievement.

Very important in the history of American zoology was the establishment, a few years after the death of Louis Agassiz, of the Woods Hole Marine Biological Laboratory (1887), *The Journal of Morphology* (1888), and the Morphological Society (1890). These enterprises were due very largely to the initiative of C. O. Whitman and brought about a solidarity of interest of the scientific zoologists of the country to which the great advances made by zoological investigation in America in recent years and the high rank it has attained in the world are largely due.

Important also has been the part taken by the various scientific departments of the United States government in furthering the study of animals. This work was begun by the Smithsonian Institution in 1846 and has been continued directly by it and the United States National Museum, the Bureau of Fisheries, the Geological and Coast Surveys, the Marine Hospital, and the various Bureaus in the Department of Agriculture. The important scientific work carried on by these institutions and the great collections they have accumulated have made Washington today the most important scientific center in the country.

3. *Subdivisions of the animal kingdom.*—The animal kingdom contains in this book eight subkingdoms or phyla. Several of these are subdivided into subphyla, and all the phyla and subphyla into classes. The classes are made up of orders, although they are sometimes first subdivided into subclasses and these into orders. The orders, and the suborders into which some of them are subdivided, are made up of families, and often subfamilies. Each family and subfamily is composed of one or more genera and each genus of one or more species. The combination of its generic with its specific name constitutes the scientific name of an animal.

The whole number of species of animals* which make up the animal kingdom is not known but probably amounts to several million. The number which has been described in scientific publications and given names in the Linnæan system of classification is considerably over half a million.

* See "On the Number of Known Species of Animals," by H. S. Pratt, Science, N. S., Vol. 35, p. 467, 1912.

The following estimates have been made of the number of the described species in each phylum:

Phylum	I.	Protozoa	8,000
Phylum	II.	Cœlenterata	7,000
Phylum	III.	Vermes	9,000
Phylum	IV.	Annelida	4,000
Phylum	V.	Arthropoda	400,000
Phylum	VI.	Mollusca	61,000
Phylum	VII.	Echinodermata	4,000
Phylum	VIII.	Chordata	37,000

Key to the phyla of the *Animal Kingdom:*

a_1 Single-celled animals, aquatic and microscopic.....1. PROTOZOA
a_2 Many-celled animals.
b_1 Body radially symmetrical.
c_1 Body with 2, 4, 6 or more, or without, definite radii.....2. CŒLENTERATA
c_2 Body with 5 radii.....7. ECHINODERMATA
b_2 Body bilaterally symmetrical.
c_1 Respiratory organs not pharyngeal.
d_1 Body without a calcareous shell (with rare exceptions).
e_1 Body not externally segmented (except in tapeworms).....3. VERMES
e_2 Body externally segmented.
f_1 No segmented locomotory appendages.....4. ANNELIDA
f_2 Paired segmented appendages present.....5. ARTHROPODA
d_2 Body with a calcareous shell.....6. MOLLUSCA
c_2 Respiratory organs internal and pharyngeal.....8. CHORDATA

PHYLUM I.

PROTOZOA.* (Single-celled Animals.)

The *Protozoa* are minute, aquatic animals which consist each of a single cell. The body, like any other animal cell, is a mass of protoplasm containing one or more nuclei. Distinct organs, in the ordinary sense, are not present, but certain specialized structures are usually found in the body which perform certain special functions. The *Protozoa* perform all the

Fig. 1

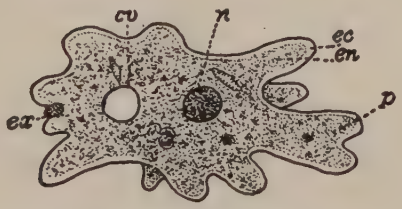

Fig. 2

Fig. 1—*Amœba limax* (Conn). Fig. 2—*Amœba proteus* (Conn); cv, *contractile vacuole;* ec, *ectosarc;* en, *entosarc;* ex, *excreta;* n, *nucleus;* p, *pseudopodium.*

essential functions which characterize the animal body. The superficial layer of the protoplasmic body is usually hyaline and distinct and is called the ectosarc (Fig. 2). It secretes in most forms a cuticula or even a hard shell which gives the body definite form. In the simplest cases, locomotion is accomplished by the thrusting out of projections called pseudopodia (Fig. 2) in the direction of movement. In the highest forms, however, cilia

* See "Protozoa," by O. Bütschli. Bronn's "Klassen u. Ord. des Thierreichs," Vol. I, 1880-1889. "A List of the Protozoa and Rotifers Found in the Illinois River," etc., by A. Hempel, Bull. Ill. St. Lab., Vol. 5, p. 301, 1898. "A Report on the Protozoa of Lake Erie," etc., by H. S. Jennings, Bull. U. S. Fish. Com., 1899, p. 105. "The Protozoa," by G. N. Calkins, 1901. "Marine Protozoa of Woods Hole," by same, Bull. U. S. Fish. Com., 1901, p. 413. "The Protozoa of the Fresh Waters of Connecticut," by H. W. Conn, Bull. No. 2, State Geol. and Nat. Hist. Survey. "The Protozoa of Iowa," by C. H. Edmondson, Proc. Acad. Sci., Davenport, 1906. "The Protozoa of Sandusky Bay," by F. L. Landacre, Proc. Ohio St. Acad. Sci., Vol. 4, p. 421, 1908 (containing a full bibliography). "Protozoology," by G. N. Calkins, 1909. "Lehrbuch der Protozoenkunde," by F. Doflein, 3d Ed., 1911. "The Protozoan Parasites of Domestic Animals," by H. Crawley, Circ. 194, Bur. An. Ind., Dep. of Ag., 1912.

(Fig. 87) or flagella (Fig. 35), which are projections of the ectosarc, are present and are permanent organs of locomotion. In a few ciliates true muscle fibres are present. Sensation is exercised by the entire surface of the body and its projections.

The inner portion of the body is called the entosarc (Fig. 2); in it nutrition is carried on. Food in solid form may be taken into the mass of the entosarc, where it is usually surrounded by a watery fluid forming the food-vacuole, and digested and absorbed. In the lower *Protozoa* the food particles are taken in through the outer surface by a simple process of engulfing, no mouth being present, but in most *Infusoria* a definite mouth is present in the ectosarc from which a gullet leads into the entosarc. Indigestible portions of the food are thrown out through an anal opening in the ectosarc which in the higher forms alone is a permanent structure. Many protozoans lead parasitic lives and absorb the vital fluids of their hosts through the outer surface of the body. Great numbers of the flagellates also closely resemble plants in their habits of nutrition. Respiration is carried on through the entire outer surface of the body, as is also excretion in most marine and parasitic *Protozoa.* In the majority of *Protozoa,* however, a special excretory organ, the contractile or pulsating vacuole (Fig. 2, cv), is present in the form of a minute globule of clear, excretory fluid which collects periodically and is then discharged to the outside through a temporary opening in the ectosarc. The contractile vacuole probably exercises a respiratory as well as an excretory function, carbon-dioxide being eliminated by its discharges.

The characteristic method of reproduction is by equal division. The nucleus takes the lead in the process and is quickly followed by the body of the cell, and two new individuals are thus formed from a single old one. In many *Protozoa* the new individuals are not completely separated from each other, but remain connected together, and a colony is thus formed, while in some a physiological division of labor occurs among the members of such a colony and an important step towards the development of a metazoan animal is taken. Still another modification of simple division is the formation of spores, which characterize the *Sporozoa* and occur occasionally in the other *Protozoa.* Spore formation may be preceded by the encystment of the animal and a period of rest; the animal draws itself together into as small a compass as possible and then secretes a firm membrane or shell within which it lies while spore formation is being accomplished. Later the cyst breaks and the spores being liberated each becomes a new individual.

Of universal occurrence among *Protozoa* is conjugation, or the temporary or permanent fusion of individuals, which in some of its phases resembles the process of fertilization in the higher animals. The two

individuals which conjugate may be either (1) similar full-sized animals, (2) full-grown animals of dissimilar size, (3) reduced individuals of similar size (similar swarm-spores), or (4) reduced individuals of dissimilar size (specialized gametes). In the last mentioned case the gametes resemble the male and female reproductive cells of the *Metazoa.*

Conjugation was formerly thought to be a process of rejuvenation by which the vital energies of the animals are renewed after the appearance of senile changes and a decrease in size and strength. It is now believed to be rather a method for the introduction of variation into a race or species, and to have thus a meaning similar to that of sexual reproduction among the *Metazoa,* a variable race being better fitted to adapt itself to a changing environment and to overcome unfavorable life-conditions.

The *Protozoa* are all, with a few exceptions, aquatic animals. When the water in which they are living dries up and at certain other times they encyst themselves, and in this condition can withstand complete desiccation a long time. *Protozoa* are easily transported by the wind, especially when encysted, and many species have a world-wide distribution.

Protozoa feed upon organic matter in every form. Certain species are carnivorous; others feed exclusively on plants; many feed on decaying substances; and many are parasitic. Of this latter kind many, especially among the *Sporozoa,* are the cause of disease both in man and animals. Many contain chlorophyll and live like plants and are consequently near the border line between plants and animals.

History.—Microscopic animals were first studied in 1675 by the Dutch naturalist Leeuwenhoek, who first used the microscope in the study of living organisms. About a hundred years later Otto Friedrich Müller described a large number of them, adopting the binomial nomenclature, and thus laid the foundation of the present classification. The name *Protozoa* originated with Goldfuss in 1820, who, however, included in the group jellyfish, hydroids, and all of the lowest animals. In 1838 Ehrenberg published his epoch-making work on *Infusoria,* including in this term all the microscopic animals, the significance of his work consisting in the fact that he brought together accurate descriptions of great numbers of these organisms. Ehrenberg was followed by Dujardin and others and in 1845 von Siebold, interpreting these simple creatures in the light of the newly established cell-theory, separated them from the *Radiata,* with which they were classed, and applied to them the name *Protozoa.* Bütschli (1880-1889) gave the classification of the group its present form.

The *Protozoa* contain 4 classes and about 8,000 species, of which the majority are radiolarians.

Key to the classes of *Protozoa:*

a_1 Cilia or flagella absent.
b_1 Pseudopodia present, sometimes with rigid, axial filaments...1. SARCODINA
b_2 Pseudopodia absent, as well as all other locomotory organs, in the adult animal .....3. SPOROZOA
a_2 Cilia or sucking tentacles, or flagella present.
b_1 Flagella present .....2. MASTIGOPHORA (*Flagellata*)
b_2 Cilia or sucking tentacles present.....4. INFUSORIA

CLASS 1. SARCODINA.*

The most primitive *Protozoa,* in which the body is usually without definite form, but in most cases possesses rigid skeletal structures. Locomotion is effected by means of pseudopodia, which are more or less temporary projections of the body. In the *Heliozoa* and *Radiolaria* these are much less changeable in form than in the *Rhizopoda* and are usually supported by a central skeletal filament. Contractile vacuoles are present except in the marine forms. Encystment and conjugation characterize all. The majority of the *Sarcodina* are marine animals and they are often present in such large numbers in the sea that the empty shells form important deposits at the bottom (*Foraminifera*). The affinities of the *Sarcodina* are with the flagellates: the young of certain forms are flagellate and in *Mastigamœba* and others the adult form has both pseudopodia and flagella. The class was first called the *Rhizopoda,* but in 1880 Bütschli substituted the term *Sarcodina* for *Rhizopoda,* giving the latter name to one of the orders. The class contains 6,000 species, most of which are *Radiolaria* and *Foraminifera,* grouped in 3 orders.

Key to the orders of *Sarcodina:*

a_1 No central capsule present; animals in both salt and fresh water.
b_1 Body naked or with shell, with very changeable pseudopodia which contain no central axial filament.....1. RHIZOPODA
b_2 Body naked or with shell, usually of spherical and relatively permanent form with delicate ray-like pseudopodia, each of which contains a central filament .....2. HELIOZOA
a_2 Central capsule present; marine animals of relatively permanent form with ray-like pseudopodia .....3. RADIOLARIA

ORDER 1. RHIZOPODA.

Body usually covered externally by a shell (but sometimes without) which is a secretion of the ectosarc, and in many cases is covered with sand or other foreign objects; pseudopodia variable in form: 2 suborders and about 1,500 species, of which 200 live in fresh and 1,300 in salt water.

Key to the suborders of *Rhizopoda:*

a_1 Rhizopoda with simple pseudopodia and with or without a shell..1. AMŒBIDA
a_2 Rhizopoda with branching and anastomosing pseudopodia and with or without a shell.....2. RETICULARIIDA

* See "Freshwater Rhizopoda of North America," by J. Leidy, Rep. U. S. Geol. Sur., etc., Vol. 12, 1879.

Suborder 1. AMŒBIDA.

Rhizopoda having lobose pseudopodia which may be finger-shaped or pointed, but are usually not reticulate; shell of chitin or silica usually present, to which sand or other foreign bodies may be attached: 3 families.

Key to the families of *Amœbida:*

a_1 Naked Amœbida .....1. Amœbidae
a_2 Amœbida with a shell.
b_1 Shell membranous, often with sand and other foreign bodies imbedded in it .....2. Arcellidae
b_2 Shell composed of regular plates of silica or chitin; pseudopodia sharp and often branching and sometimes slightly anastomosing....3. Euglyphidae

Family 1. AMŒBIDAE.

Shell-less *Rhizopoda,* whose pseudopodia are not reticulate; body without definite form and under ordinary conditions constantly changing its shape by throwing out pseudopodia, although covered by a cuticula of greater or less delicacy: about 19 genera, with numerous species in both fresh and salt water.

Key to the genera of *Amœbidae* here described:

a_1 Nucleus absent .....1. Protamœba
a_2 Nucleus present and usually distinct.
b_1 Numerous nuclei, vacuoles, and retractile bodies present.....2. Pelomyxa
b_2 Numerous nuclei, vacuoles, and retractile bodies not present.
c_1 Pseudopodia membrane-like, ectosarc reddish.....3. Plakopus
c_2 Pseudopodia not membrane-like.
d_1 Pseudopodia more or less lobose, sometimes slender and spine-like.
e_1 Animals not parasitic.....4. Amœba
e_2 Animals parasitic.....5. Entamœba
d_2 Pseudopodia very long, radiating spine-like from body.
6. Dactylosphærium

1. Protamœba Haeckel. Minute forms without nucleus or contractile vacuole, in constant motion, with short pseudopodia: 4 species; in salt and fresh water.

P. primitiva Haeckel. In fresh and salt water.

2. Pelomyxa Greeff. Very large forms constantly flowing by means of short pseudopodia; body with numerous nuclei, vacuoles and hyaline rods; diameter up to 2 mm.: 4 species; in fresh water.

P. palustris Greeff. Without projections at hinder end.

P. villosa Leidy. Possesses numerous posterior projections; about 1 mm. in length; body dark and opaque.

P. carolinensis H. V. Wilson. No rods present, but numerous minute crystals; 1 mm. in diameter.

3. Plakopus F. E. Schulze. Body changes slowly in form and with pointed pseudopodia which are often joined together by a broad membrane: 2 species; in fresh water.

P. ruber F. E. Schulze. Color reddish: in fresh water.

4. **Amœba** Ehrenberg. Body may assume a variety of forms, being often more or less spherical while at rest; pseudopodia either slender or lobose; nucleus and contractile vacuole present: about 12 species; in fresh and salt water.

A. limax Dujardin (Fig. 1). Body small, elongate, without definite pseudopodia and moves by slowly flowing along: in fresh water.

A. proteus (Pallas) (Fig. 2). Diameter up to .5 mm.; pseudopodia long and usually blunt; movements often active: in fresh water.

A. radiosa Ehr. Pseudopodia slender and radiating; body more or less star-shaped; diameter about .04 mm.: on water plants.

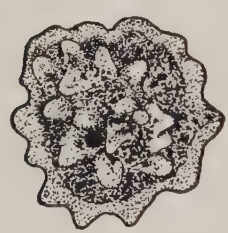

Fig. 3

Fig. 4

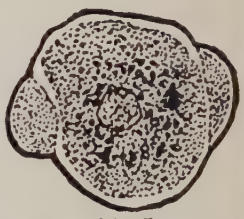

Fig. 5

Fig. 3—*Amœba verrucosa* (Conn). Fig. 4—*Entamœba coli* (Doflein). Fig. 5—*Entamœba dysenteriae* (Doflein).

A. verrucosa Ehr. (Fig. 3). Diameter up to .2 mm.; pseudopodia short; surface folded; movements sluggish.

5. **Entamœba** Casagrandi and Barbagallo. Similar to *Amœba,* but parasitic in mammals; size minute; pseudopodia short and sluggish: several species.

E. coli (Loesch) (Fig. 4). Form roundish or elongate with a distinct nucleus and an indistinct ectosarc; pseudopodia short and sluggish; diameter .06 mm.: in human colon; formerly supposed to be a cause of dysentery.

E. dysenteriae (Councilman and Lafleur) (*E. histolytica* Schaudinn) (Fig. 5). Similar to *E. coli* but with a distinct ectosarc: in the human colon; the cause of dysentery.

6. **Dactylosphærium** Hertwig and Lesser. Small round forms with often numerous long ray-like pseudopodia, which sometimes vibrate slightly; short and blunt pseudopodia also present when the animal moves: in fresh water.

D. radiosum (Ehrenberg). Three or 4 long spine-like pseudopodia; diameter .02 mm.

D. polypodia F. E. Schulze. Numerous finger-like pseudopodia present.

Family 2. ARCELLIDAE.

Shell membranous and consisting of a single chamber, the surface of which is either smooth or covered with sand or other foreign particles; single opening usually present from which blunt pseudopodia protrude: fresh-water animals of minute size; 10 genera and about 30 species.

Key to the genera of *Arcellidae* here described:

a_1 Shell covered with sand or other foreign bodies.....1. Difflugia
a_2 Shell not covered with foreign bodies.
b_1 Shell composed of quadrilateral plates.....2. Quadruella
b_2 Shell of one piece, not composed of plates.
c_1 Shell flexible and more or less disc-like; 1 to 3 openings..3. Cochliopodium
c_2 Shell disc-shaped and not flexible.
d_1 Rim of shell without spines.....4. Arcella
d_2 Rim of shell with spines.....5. Centropyxis

1. Difflugia Leclerc. Shell covered with sand-grains or other foreign bodies, pear-shaped or spherical, frequently with spines at the sides or hinder end, and with a large opening at the other end from

Fig. 6

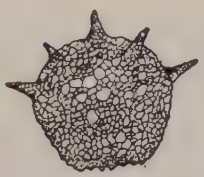

Fig. 7

Fig. 8

Fig. 6—*Difflugia lobostoma* (Conn). Fig. 7—*Difflugia corona* (Leidy). Fig. 8—*Quadruella symmetrica* (Leidy).

which a number of blunt pseudopodia may project; nucleus and contractile vacuoles always present: about 20 species, which are very variable in form; in fresh-water pools, usually on plants or on the bottom.

D. lobostoma Leidy (Fig. 6). Shell spherical or ovate, the oral pole truncated; mouth usually 3 to 6 lobed; aboral end rounded; length .12 mm.: common.

D. pyriformis Perty. Shell bottle-shaped with a cylindrical neck more or less distinct; length up to .6 mm.: common.

D. urceolata Carter. Shell jug-shaped with short neck and often a rim; hinder end pointed or rounded; length up to .52 mm.

D. constricta Ehrenberg. Shell ovoid; mouth oblique; aboral end rounded, often with spines; length up to .3 mm.

D. globulosa Dujardin. Shell spheroidal or oval; mouth circular; length .2 mm. or less: rather common.

D. acuminata Ehr. Shell oval; aboral end acute, often prolonged, rarely with 2 or 3 points; length .4 mm.

D. corona Wallich (Fig. 7). Shell spheroid with a number of long spines at hinder end; length up to .32 mm: very common.

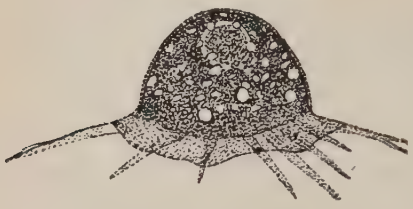

Fig. 9—*Cochliopodium bilimbosum* (Leidy).

2. Quadruella Cockerell. Shell pear-shaped and composed of quadrilateral silicious plates, with occasional spines at the hinder end: several species; in fresh water.

Q. symmetrica (F. E. Schulze) (Fig. 8). Length up to .14 mm.: in swamps.

3. Cochliopodium Hertwig and Lesser. Shell minute, spheroid or disc-like, without foreign bodies, and flexible, changing in shape: 3 species; in fresh water.

C. bilimbosum Auerbach (Fig. 9). Diameter up to .05 mm.; opening large, the acute pseudopodia protruding: among algae, etc., in fresh water.

C. digitatum Calkins. Several openings through which pseudopodia protrude.

4. Arcella Ehrenberg. Shell yellow or brown and smooth, not being covered with sand, convex on one side, and flat or concave on the other, in the middle of which is the opening; nuclei and contractile vacuoles 2 or more: several species; in fresh water, also in moist sand and moss.

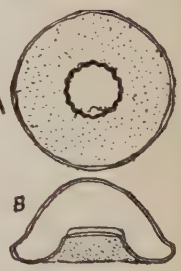

Fig. 10

Arcella vulgaris (Leidy). A, under view of shell; B, side view.

A. vulgaris Ehr. (Fig. 10). Diameter about .15 mm.; margin not scalloped: very common.

A. dentata Ehr. (Fig. 11). Diameter about .18 mm.; margin scalloped.

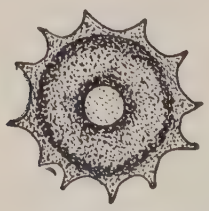

Fig. 11

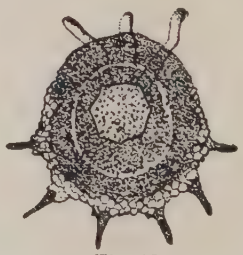

Fig. 12

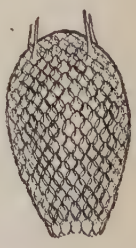

Fig. 13

Fig. 11—*Arcella dentata* (Leidy). Fig. 12—*Centropyxis aculeata* (Leidy). Fig. 13—*Euglypha alveolata* (Leidy).

5. Centropyxis Stein. Shell similar to *Arcella,* but with spines, variable in number, and sometimes elongate: in ditches and pools.

C. aculeata Stein (Fig. 12). Diameter of shell .2 mm.

Family 3. EUGLYPHIDAE.

Shell membranous and composed of plates of chitin or silica enclosing a single chamber with a single large opening; pseudopodia filiform and sometimes somewhat anastomosing; size minute: 5 genera; mostly in fresh water.

1. Euglypha Dujardin. Shell elongate, ovate, often with spines at hinder end and composed of oblique rows of round plates whose edges overlap, making hexagonal areas; opening denticulate; pseudopodia fine, often branching but not reticulate: in fresh water; 4 species.

E. alveolata Duj. (Fig. 13). Shell colorless, elongated and cylindrical; hinder end broader, usually with a few long spines; plates composing it are round or oval; length .15 mm.: common.

E. ciliata Leidy. Shell elongate and elliptical in cross section; hinder end and sides with numerous short spines; plates six-sided; length .1 mm.: common in sphagnum moss.

Fig. 14
Cyphoderia ampulla (Leidy).

2. Cyphoderia Schlumberger. Shell retort-shaped and composed of minute plates; opening turned to one side; forward half of body contains numerous contractile vacuoles, and hinder half the nucleus; color yellowish: 2 species; in fresh and salt water.

C. ampulla (Ehrenberg) (Fig. 14). Length .17 mm.: in ponds and ditches.

Suborder 2. RETICULARIIDA.

Pseudopodia filiform and reticulate; calcareous shell usually present which has either one or more large openings or many minute ones, through which the pseudopodia project: 3 divisions.

Key to the divisions of *Reticulariida:*

a_1 No shell present.....1. Nuda
a_2 Shell with one or more large and no minute openings.....2. Imperforina
a_3 No large but numerous minute openings.....3. Perforina

Division 1. NUDA.

Rhizopods without shell and with reticulate pseudopodia: about 8 genera; mostly marine.

Biomyxa Leidy. Form incessantly changing; nucleus present or apparently absent: 1 species.

B. vagans Leidy. Color pale gray with oil globules, nucleus when present large and distinct; no ectosarc: in sphagnum moss.

Division 2. IMPERFORINA.

Rhizopods with shell which has one or more large openings from which project reticulate and anastomosing pseudopodia; shell usually calcareous, but sometimes membranous, to which sand may adhere, and one or many chambered: 4 families.

Family GROMIIDAE.

Marine and fresh-water rhizopods with a membranous shell with an opening at one or both ends: 10 genera.

Key to the genera of *Gromiidae* here described:

a_1 Shell with but one opening.
b_1 Pseudopodia richly anastomosing; contractile vacuoles usually present. 1. Gromia
b_2 Pseudopodia anastomosing little: numerous contractile vacuoles. 2. Pamphagus
a_2 Shell with an opening at each end.....3. Diplophrys

Fig. 15—*Gromia lagenoides* (Calkins).

1. Gromia Dujardin. Shell spherical or ovate in shape and entirely filled by the protoplasmic body; shell membranous and often flexible, changing its shape; pseudopodia very fine and reticulate; nuclei one or many: several species; in fresh and salt water.

G. lagenoides Gruber (Fig. 15). Body about .25 mm. long, with opening at larger end of shell; edge of opening turned in; a fine layer of protoplasm surrounds the shell which has fine reticulate pseudopodia on all sides of it; shell either with or without foreign bodies: Woods Hole; not numerous.

2. Pamphagus Bailey. Pseudopodia very delicate, springing from a common protoplasmic base and not anastomosing; shell flexible and delicate, and filled by the protoplasmic body; opening of shell narrow: 7 species.

P. mutabilis Bailey. Body compressed and ovate or pear-shaped; protoplasm yellowish in color; length 1 mm.: in swamps.

P. hyalinus Leidy. Body almost spherical with short neck; often colonial; length .04 mm.

3. **Diplophrys** Barker. Shell spherical and membranous and with two openings opposite each other, from which protrude the pseudopodia: 2 species; in fresh water.

D. archeri Barker. Pseudopodia not always anastomosing; length .02 mm.

Division 3. **PERFORINA.** (Foraminifera.)

Calcareous shell, either one or many chambered, and with numerous minute pores, as well in some cases as large openings, through which stream reticulate pseudopodia: 9 families with numerous genera and over 1,200 species, most of which live in the mud of the sea bottom, about 20 species being pelagic.

Family GLOBIGERINIDAE.

Shell calcareous and one or many chambered with one or more large openings: about 7 genera.

Globigerina D'Orbigny. Shell with many chambers which are more or less ovoid and spirally arranged; large openings crescentic; usually with spines: about 13 species; marine.

G. bulloides D'Orb. Animals pelagic and also in the bottom mud at all depths down to 3,000 fathoms: cosmopolitan.

Order 2. **HELIOZOA.***

Sarcodina with little power of amœboid movement, with a silicious skeleton and fine ray-like pseudopodia which are often supported by silicious axial filaments; ectosarc and entosarc usually sharply marked; contractile vacuole present in the fresh-water forms, but absent in the marine ones; either one or several nuclei present; reproduction either by equal division or by spore formation, the spores being flagellate and after an active life losing their flagella and assuming the form of the adult; conjugation and encystment also occur: about 50 species, grouped in 4 suborders; mostly in fresh water, but also in the sea and in moist earth.

Key to the suborders of *Heliozoa:*

a_1 Heliozoa without skeleton.
b_1 Body naked .....1. Aphrothoracida
b_2 Body with a soft gelatinous or felted fibrous covering..2. Chlamydophorida
a_2 Heliozoa with skeleton.
b_1 Skeleton consists of spicules.....3. Chalarathoracida
b_2 Skeleton consists of a single piece perforated by numerous openings.
4. Desmothoracida

* See "Heliozoa," by F. Schaudinn, Das Tierreich, 1896.

Suborder 1. APHROTHORACIDA.

Naked *Heliozoa* with filiform pseudopodia radiating from all sides which are either with or without axial filaments; one or more nuclei and contractile vacuoles present: 9 genera.

Key to the genera of *Aphrothoracida* here described:

a_1 Body more or less amœboid.
  b_1 Ectosarc and entosarc sharply defined; animals appear on algae as red cysts ..... 1. Vampyrella
  b_2 No boundary between ectosarc and entosarc ..... 2. Nucleraria
a_2 Body not amœboid; form spherical.
  b_1 Ectosarc and entosarc not defined; skeletal axis of pseudopodia extending to center ..... 3. Actinophrys
  b_2 Ectosarc and entosarc sharply separated ..... 4. Actinosphærium

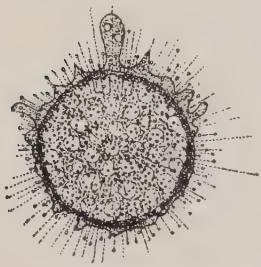

Fig. 16

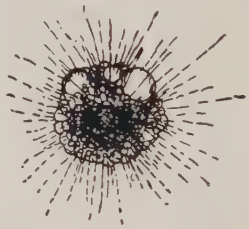

Fig. 17

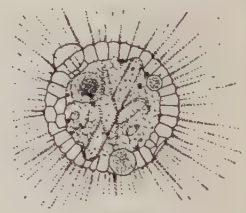

Fig. 18

Fig. 16—*Vampyrella lateritia* (Leidy). Fig. 17—*Actinophrys sol* (Leidy). Fig. 18—*Actinosphærium eichhorni* (Leidy).

1. Vampyrella Cienkowsky. Ectosarc hyaline; entosarc brown or red, frequently vacuolated; form amœboid, pseudopodia radiating from all sides or arising from only one place: 5 species; in fresh and salt water.

V. lateritia Leidy (Fig. 16). Body spherical or elongated; diameter about .06 mm.; length of moving animals may be .24 mm.: among fresh-water algae.

2. Nucleraria Cienkowsky. Body spherical or elongate and amœboid with homogeneous protoplasm; pseudopodia radiating from all sides or arising from only one place; one or more nuclei and many contractile vacuoles: 2 species; in fresh water.

N. simplex Cienk. Diameter about .05 mm.: among *Spirogyra* and other fresh-water plants.

3. Actinophrys Ehrenberg. Body spherical and not amœboid; pseudopodia radiating from all sides and with axial threads which extend to center of body; ectosarc and entosarc not separate: 1 species; in fresh and salt water.

A. sol (O. F. Müller) (Fig. 17). Diameter .05 mm.; often colonial: common.

4. Actinosphærium Stein. Like *Actinophrys* but with sharply defined and vacuolated ectosarc: 1 species.

A. eichhorni (Ehrenberg) (Fig. 18). Diameter up to 1 mm.: in fresh water; common.

Suborder 2. CHLAMYDOPHORIDA.

Body spherical and with a soft gelatinous or felted covering in which foreign bodies may be present: 5 genera.

Heterophrys Archer. Body with a slight differentiation into ectosarc and entosarc; pseudopodia radiating from all sides: 2 species; in fresh and salt water.

H. myriapoda Archer. Diameter .08 mm.; pseudopodia twice as long as diameter of body; chlorophyll bodies often present: in fresh and salt water.

Suborder 3. CHALARATHORACIDA.

Isolated silicious needles present which cover the outer surface: 8 genera.

1. Raphidiophrys Archer. Body spherical, covered with silicious needles lying tangentially; ectosarc and entosarc not distinct; pseudopodia with axial threads radiating from all sides; often forming colonies which have a common covering: 4 species; in fresh water.

R. elegans Hertwig and Lesser. Diameter .04 mm.; often with chlorophyll bodies: in fresh water.

2. Acanthocystis Carter. Spherical animals in which the silicious needles project radially; between them are the thread-like pseudopodia, each with an axial thread; tangential needles may also be present: 10 species; in fresh water.

A. chætophora (Schrank). Diameter .1 mm.; needles of 2 forms, a short and a long, both forked, and both with basal plates.

Suborder 4. DESMOTHORACIDA.

Body enclosed in a silicious spherical shell containing numerous round holes; a central nucleus; many contractile vacuoles and filiform pseudopodia: 2 genera.

Clathrulina Cienkowsky. Body spherical and fastened by a stalk to some fixed object; the body does not fill the shell, which is absent in the young individuals: 2 species; in fresh water.

C. elegans Cienk. (Fig. 19, p. 24). Diameter of shell .07 mm.; length of stalk up to .3 mm.: in pools.

Order 3. RADIOLARIA.

Marine *Sarcodina* often of large size, with ray-like pseudopodia; silicious skeleton present in most cases, which is often of great complexity and beauty; pseudopodia usually with axial filaments; body divided into two regions, the central capsule and the extra-capsular portion; capsule surrounded by a perforated chitinous membrane and occupying the center of the body containing also one or more nuclei and often oil globules; extra-capsular protoplasm often vacuolated and pigmented and containing often yellow unicellular algae (*zooxanthellae*) which live symbiotically in it; no contractile vacuole present; reproduction by division, the central capsule dividing first; in some forms the central capsule alone divides, and a colony is the result; spore formation has also been observed, in which flagellate spores are formed in the central capsule: about 85 families and over 4,300 species, which are found mostly in the deep sea.

Fig. 19
Clathrulina elegans (Conn).

Family THALASSICOLLIDAE.

Skeleton wanting; central capsule simple, with a single nucleus.

Thalassicolla Huxley. Extra-capsular portion filled with alveoli among which are numerous yellow algae.

T. pelagica Haeckel. Diameter 2 mm.: in the Mediterranean.

Class 2. MASTIGOPHORA. (Flagellata.)

Protozoa whose motile organs consist of one or more long whip-like projections called flagella. The body is provided with an external membrane which, in many cases, is very delicate, the body being more or less amœboid. A membranous shell of silica, chitin, or cellulose is also often present. In one group, the *Choanoflagellida,* the base of the single flagellum is surrounded by a high ridge called the collar (Fig. 28). A single nucleus is present, and usually a contractile vacuole.

The protoplasm usually shows no division into ectosarc and entosarc. It often contains chromatophores which may be formed of chlorophyll and green, or of diatomin and yellow or brown in color. Other bodies allied to starch or oil are often present imbedded in the protoplasm. Reproduction is by division and by spore formation; colony formation, the result of incomplete division, is very common, the members of the colony being sometimes enclosed in a common cellulose jelly, sometimes connected by protoplasmic strands, and sometimes joined by both jelly

and strands. The colony is in some cases very complex with division of labor among the different individuals.

The *Mastigophora* have been known from the earliest period of the study of microscopical animals under the general name of *Flagellata*, and are still so known in many textbooks. The name *Mastigophora* was given the group by Bütschli in 1883. The animals live in both fresh and salt water, and many are parasites in the higher animals, being often the cause of disease. Large numbers closely resemble plants and many are on the border line between animals and plants. The class contains 3 subclasses with about 350 species.

Key to the subclasses of *Mastigophora:*

a_1 Small Mastigophora with a definite anterior and posterior end, at one or the other of which are 1 or more flagella.....1. FLAGELLIDIA
a_2 Mastigophora with usually 2 flagella, 1 anterior and 1 transverse in position .....2. DINOFLAGELLIDIA
a_3 Large marine Mastigophora with parenchymatous protoplasm.
3. CYSTOFLAGELLIDIA

SUBCLASS 1. FLAGELLIDIA.

Body with a well-defined cuticula which gives it a definite shape, the cuticula in some forms, however, being so thin that changes in shape often take place; pseudopodia formed in certain forms; many flagellates are protected by external coverings of jelly, chitin, silica or cellulose; 1, 2 or several flagella extend from one end of the body, usually the forward; in the *Choanoflagellida,* however, the single flagellum is at the hinder end and is surrounded at its base by a collar: 8 orders, in which are included the great majority of flagellates, very many containing chromatophores and being apparently allied to plants.

Key to the orders of *Flagellidia:*

a_1 Body colorless, often more or less amœboid, and with one or more flagella.
b_1 Body spiral with or without flagellum, and more or less like bacteria.
1. SPIROCHETIDA

b_2 Body not spiral.
c_1 One flagellum with collar present.....3. CHOANOFLAGELLIDA
c_2 No collar present.
d_1 Body with indistinct cuticula, often more or less amœboid.
e_1 Body elongate with undulating membrane.....5. TRYPANOSOMATIDA
e_2 No undulative membrane present.
f_1 Two or more flagella, one directed forward, the other trailed behind.
4. HETEROMASTIGIDA

f_2 Flagella always directed forward.
g_1 One or two flagella; body usually more or less amœboid..2. MONADIDA
g_2 Three or more flagella.....6. POLYMASTIGIDA
d_2 Body with distinct cuticula.....7. EUGLENIDA
a_2 Body usually either yellow or green, often colonial.
b_1 Body with distinct cuticula, and usually solitary.....7. EUGLENIDA
b_2 Body usually with a hyaline, gelatinous or cellulose house; colonial.
8. PHYTOFLAGELLIDA

Order 1. SPIROCHETIDA.

Body elongate, spiral, with or without an undulating membrane; flagellum very short or absent; nucleus diffuse: 1 family.

Family SPIROCHETIDAE.

With the characters of the order: 3 genera.

1. **Spirocheta** Ehrenberg. Undulating membrane but no flagellum present: about a dozen species; mostly parasitic.

Fig. 20

Fig. 21

Fig. 20—*Spirocheta balbianii* (Doflein).
Fig. 21—*Spirocheta plicatilis* (Doflein).

S. balbianii (Certes) (Fig. 20). Length .02 to .18 mm.; broad membrane present; ends rounded: in the digestive tract of the oyster, often in the crystalline style.

S. plicatilis Ehr. (Fig. 21). Length .08 to .2 mm.; narrow membrane present; ends rounded: in stagnant water.

2. **Treponema** Schaudinn. Flagellum but no undulating membrane present: about 8 species.

Fig. 22

Treponema pallidum (Doflein).

T. pallidum Schaudinn (Fig. 22). Body cylindrical, without membrane, .015 mm. long; ends tapering, ending each in a fine flagellum: in syphilitic lesions.

Order 2. MONADIDA.

Body usually without shell and more or less amœboid, with 1 or 2 large flagella at the forward end and often 1 or more secondary flagella; no mouth: 5 families.

Key to the families of *Monadida* here described:

a_1 Pseudopodia present ..... 1. Rhizomastigidae
a_2 Pseudopodia absent.
  b_1 One flagellum present.
    c_1 Body not in a cup..... 2. Cercomonadidae
    c_2 Body in a cup..... 3. Codonecidae
  b_2 Two flagella present..... 4. Heteromonadidae

Family 1. RHIZOMASTIGIDAE.

Simple forms without mouth and with 1 or 2 flagella; occasionally with either lobose pseudopodia like a rhizopod or stiff radial ones like a heliozoan; food taken at any part of the body: 6 genera.

Mastigamœba F. E. Schulze. Body irregular in form with several pseudopodia which disappear when the animal swims, and one long flagellum: 6 species; in fresh and salt water.

M. verrucosa Kent (Fig. 23). Length about .015 mm.; many short pseudopodia: in fresh water.

M. simplex Calkins. Ectosarc and entosarc distinct; flagellum converted into a pseudopodium; length .01 mm.: marine, on decaying algae.

Family 2. CERCOMONADIDAE.

Body oval or elongate, frequently amœboid, especially at hinder end; with pseudopodia and with a long flagellum: 5 genera.

1. **Cercomonas** Dujardin. Form more or less spindle-shaped, prolonged posteriorly: 3 species; in fresh water.

C. longicauda Duj. Tail long; length up to .05 mm.

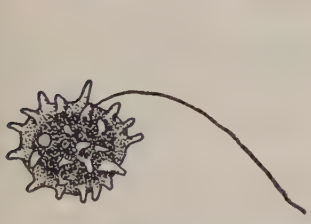

Fig. 23

Fig. 24

Fig. 25

Fig. 23—*Mastigamœba verrucosa* (Calkins). Fig. 24—*Herpetomonas muscae domesticae* (Doflein). Fig. 25—*Codoneca gracilis* (Calkins).

2. **Herpetomonas** Kent. Body elongate, very flexible; hinder end often the more attenuate, but not forming a caudal filament: several species; parasitic in insects.

H. muscae domesticae (Burnett) (Fig. 24). Length .05 mm.: in intestine of the house-fly; common.

3. **Oikomonas** Kent. Form spherical or oval; frequently a projecting lip at base of flagellum; sometimes attached by a terminal filament: several species in fresh and salt water, often in infusions.

O. termo (Ehrenberg). Length .06 mm.: often very common in fresh water.

Family 3. CODONECIDAE.

Body enclosed in a gelatinous or hyaline cup: 2 genera.

Codoneca Clark. Ovoid or goblet-shaped, and attached to a caudal stalk; animal does not fill cup: 3 species; in fresh and salt water.

C. gracilis Calkins (Fig. 25). Cup urn-shaped with a distinct neck; length .021 mm.: Woods Hole.

Family 4. HETEROMONADIDAE.

One or 2 accessory flagella present besides the main one; often sessile or colonial, the animals being on a common stalk: 3 genera.

Key to the genera of *Heteromonadidae:*

a_1 Solitary forms ..... 1. MONAS
a_2 Colonial forms.
  b_1 Common stalk branched once or twice; on Cyclops.. 2. CEPHALOTHAMNIUM
  b_2 Common stalk much branched..... 3. ANTHOPHYSA

1. **MONAS** Ehrenberg. Body spherical or ovate, occasionally fastened by a thread-like stalk; 2 flagella: 3 species; in fresh water.

Fig. 26

Fig. 27

Fig. 28

Fig. 26—*Monas elongata* (Conn). Fig. 27—*Cephalothamnium cæspitosum* (Conn). Fig. 28—*Monosiga ovata* (Calkins).

M. elongata (Stokes) (Fig. 26). Body elongate; hinder end tapers to form stalk; length .01 mm.

2. **CEPHALOTHAMNIUM** Stein. Body ovate, with one long and one short flagellum; animals colonial and sessile, the stalk branching two or three times and several individuals being grouped at the end of each branch: 2 species; in fresh water, often on *Cyclops.*

C. cæspitosum (Kent) (Fig. 27). Body with obliquely truncated anterior end; length of individual .02 mm.

3. **ANTHOPHYSA** Bory. Body as in above; stalk much branched: 1 species; in fresh water.

A. vegetans (O. F. Müller). Length of individual .03 mm., of colony .4 mm.

ORDER 3. CHOANOFLAGELLIDA.

Collar flagellates. Collar-like ridge surrounding the base of the single flagellum which is at the hinder end of the body when the animal swims, instead of at the forward end as in other flagellates; in some forms 2 collars are present, one over the other: 2 families.

FAMILY CRASPEDOMONADIDAE.

Either solitary or colonial and either free-swimming or sessile and often enclosed in a cup or a gelatinous envelope: 4 genera.

Key to the genera of *Craspedomonadidae:*

a_1 Shell wanting; animals sessile or stalked.
  b_1 Stalk shorter than body or wanting..... 1. MONOSIGA
  b_2 Stalk long, with many individuals at the end..... 2. CODONOSIGA
  b_3 Stalk long, branched at end..... 3. CODONOCLADIUM
a_2 Shell present ..... 4. SALPINGŒCA

1. Monosiga Kent. Small colorless forms, solitary and sessile, attached directly or by a short stalk: 9 species; in fresh and salt water.

M. ovata Kent (Fig. 28). Individual ovate or spherical; length .08 mm.: in fresh and salt water.

2. Codonosiga Clark. Similar to *Monosiga,* but at the end of a stalk and solitary or colonial: 1 species.

C. botrytis Clark. From 1 to 20 individuals in a colony; length of individual .08 mm., of stalk .014 mm.: in fresh and salt water.

3. Codonocladium Stein. Like *Codonosiga,* but the stalk branches, each branch bearing an individual: 4 species; in fresh and salt water.

C. umbellatum Stein. Number of branches 4 to 10, which sometimes also branch; length .03 mm.: in fresh water.

4. Salpingœca Clark. Solitary; body enclosed in a shell, usually cup-shaped, which is directly attached at base or at the end of a short stalk: about 27 species; in fresh and salt water.

S. steini Kent. Shell cylindrical; length .02 mm.: in fresh water.

Order 4. HETEROMASTIGIDA.

Two or more flagella present, one of which is directed forwards and the others backwards, during locomotion; no shell present; animal colorless: 2 families.

Family BODONIDAE.

Small, naked forms with 2 flagella of nearly equal length: 4 genera.

Key to the genera of *Bodonidae* here described:

a_1 Flagella spring from anterior end.
  b_1 Flagella longer than body, which is ovate.....1. Bodo
  b_2 Flagella shorter than body, which is elongate.....2. Phyllomitus
a_2 Flagella spring from a lateral groove.....3. Oxyrrhis

Fig. 29

Fig. 30

Fig. 31

Fig. 29—*Bodo caudatus* (Calkins). Fig. 30—*Phyllomitus amylophagus* (Conn). Fig. 31—*Oxyrrhis marina* (Calkins).

1. Bodo Ehrenberg. Body more or less ovate, often amœboid; anterior end pointed, with 2 flagella arising from a slight depression: 10 species; in salt and fresh water.

B. caudatus (Dujardin) (Fig. 29). Body ovate, often amœboid; flagella about the same length; length .018 mm.

2. **Phyllomitus** Stein. Body elongate and very flexible, with 2 flagella shorter than the body: 1 species.

P. amylophagus Klebs (Fig. 30). Length .018 mm.: in fresh water.

3. **Oxyrrhis** Dujardin. Body oval with pointed hinder end, at side of which is a deep cavity from which the flagella emerge: 1 species; marine.

O. marina Duj. (Fig. 31). Length .04 mm.: at Woods Hole.

Order 5. TRYPANOSOMATIDA.

Body elongate, usually pointed, with an undulating lateral membrane and 1 or 2 flagella which arise from a special nucleus (blepharoplast) and accompany the membrane as a lateral chord: 1 family.

Family TRYPANOSOMIDAE.

With the characters of the order: several genera; parasitic in invertebrate and vertebrate hosts and often the cause of deadly diseases.

Fig. 32

Fig. 33

Fig. 34

Fig. 32—*Trypanosoma gambiense* (Doflein). Fig. 33—*Trypanosoma brucei* (Doflein). Fig. 34—*Hexamitus inflatus* (Conn).

Trypanosoma Gruby. But 1 flagellum present: over 60 species, which are parasites of the blood system in all kinds of vertebrates and are also found in the intestine of various blood-sucking insects, which in many cases are known to convey the parasite to the vertebrate host by their bite.

T. gambiense Dutton (Fig. 32). The cause of the deadly sleeping sickness which affects man in western and central Africa; it is conveyed by *Glossina palpalis,* a tsetse fly; length .03 mm.

T. brucei Plimmer and Bradford (Fig. 33). The cause of nagana, a sickness fatal to horses and cattle and other animals in Africa and is conveyed by *Glossina morsitans,* a tsetse fly.

T. evansi Steel. The cause of surra,* a fatal disease to horses and cattle in Africa, Asia, and America and conveyed by horse flies.

Order 6. POLYMASTIGIDA.

Three or more flagella and usually several mouth openings present; body colorless and without shell: 3 families.

* See "Collected Studies on the Insect Transmission of Trypanosoma evansi," by M. B. Mitzmain, Bull. 94, Hyg. Lab., Wash., 1914.

Family DISTOMIDAE.

Flagella in two symmetrical groups, with a mouth at the base of each: 2 genera.

Hexamitus Dujardin. Body ovate, with 2 to 4 flagella at forward end and hinder end prolonged into 2 thread-like processes: 3 species; in fresh water, also parasitic in intestine of amphibians.

H. inflatus Duj. (Fig. 34). Posterior processes not close together; length .027 mm.

Order 7. EUGLENIDA.

Large forms with usually a distinct, spirally striped cuticula; 1 or 2 flagella present at the forward end, with a so-called pharynx at their base and a contractile vacuole opening into the pharynx; frequently colonial and usually colored by chromatophores in which 1 or more deeply staining bodies, the pyrenoids, may be present; paramylum, a substance allied to starch, also usually present: 3 families.

Key to the families of *Euglenida:*

a_1 Chlorophyll usually present.....1. Euglenidae
a_2 Chlorophyll absent.
b_1 Without distinct mouth; saprophytic.....2. Astasiidae
b_2 With distinct mouth; holozoic.....3. Paranemidae

Family 1. EUGLENIDAE.

Body spindle or pear-shaped with usually a single flagellum; chlorophyll, pyrenoids, and paramylum and an eye-spot almost invariably present; contractile vacuole or vacuoles open into a reservoir which opens into the pharynx; nutrition mostly holophytic, in some cases saprophytic: 6 genera.

Key to the genera of *Euglenidae:*

a_1 With one flagellum.
b_1 Cuticula elastic, animals more or less plastic.
c_1 Animal not in a shell.
d_1 Animal free-swimming .....1. Euglena
d_2 Usually attached to other animals.....2. Colacium
c_2 Animal in a shell.....3. Trachelomonas
b_2 Cuticula not elastic and animal not plastic.
c_1 Chromatophores disc-shaped .....4. Phacus
c_2 Chromatophores in two longitudinal bands.....5. Cryptoglena
a_2 With two flagella.....6. Eutreptia

1. Euglena Ehrenberg. Large spindle-shaped flagellates with spirally marked cuticula; 1 flagellum, at the base of which are the pharynx, eye-spot, and contractile vacuole; color usually green or red, a few being colorless: species numerous; in fresh and brackish water.

E. viridis Ehr. (Fig. 35). Length .1 mm. or less; body lenticular: often very common in pools, which it may color green.

E. acus Ehr. Body very long, even filiform, pointed behind; length .18 mm.

Fig. 35 *Euglena viridis* (Doflein).

E. deses Ehr. Body elongate, .2 mm. long, with nearly parallel sides: common.

2. **Colacium** Ehrenberg. Like *Euglena,* but usually attached by a short stalk at the forward end to small animals; flagellum present in free-swimming condition, but usually not present when attached: 3 species; in fresh water.

C. steini Kent. On *Diaptomus;* length .04 mm.

3. **Trachelomonas*** Ehrenberg. Like *Euglena,* except the animal has a brown or colorless shell: numerous species; in fresh and salt water.

T. lagenella Stein. Shell ovoid or cylindrical and smooth; length .03 mm.

T. hispida (Perty). Shell ovoid, covered with spines and usually dark brown in color; length .03 mm.

T. armata Ehr. (Fig. 36). Shell brown, punctate; 2 rows of spines around aperture and spines often around posterior end; length .04.

4. **Phacus** Nitzsch. Body somewhat asymmetrical, flattened or pear-shaped, with spiral strips; hinder end spine-like; chromatophores disc-shaped: 6 species; in fresh water.

P. pyrum (Ehrenberg) (Fig. 37). Body top-shaped; length .03 mm.

P. longicaudus Dujardin. Hinder spine very long; length .08 mm.

5. **Cryptoglena** Ehrenberg. Body oval, rigid, with 2 lateral green chromatophores and an eye-spot: 1 species.

C. pigra Ehr. Length .015 mm.: in fresh water.

Fig. 36

Fig. 37

Fig. 36 — *Trachelomonas armata* (Palmer). Fig. 37—*Phacus pyrum* (Conn).

6. **Eutreptia** Perty. Like *Euglena,* but with 2 flagella; body very flexible; chromatophores disc-shaped: 1 species.

E. viridis Perty. Length .05 mm.: in fresh water.

Family 2. ASTASIIDAE.

Elongated, colorless, more or less amœboid flagellates without eye-spot and usually with striped membrane; sometimes with an accessory flagellum: 6 genera.

* See "Delaware Valley Forms of Trachelomonas," by T. C. Palmer, Proc. Acad. Nat. Sci., 1905.

Key to the genera of *Astasiidae* here described:

a_1 Body very flexible.....1. ASTASIA
a_2 Body rigid, sickle-shaped.....2. MENOIDIUM

1. **ASTASIA** Ehrenberg. Body spindle-shaped; very plastic, with striped cuticula: 2 species; in fresh and salt water.

A. contorta Dujardin (Fig. 38). Length .06 mm.: in decaying vegetation.

2. **MENOIDIUM** Perty. Body elongate and more or less bent, and rigid; cuticular stripes longitudinal: 1 species.

M. pellucidum Perty. Length .08 mm.: in fresh water.

Fig. 38
Astasia contorta (Calkins).

FAMILY 3. PERANEMIDAE.

Body usually cylindrical or ovate, plastic or rigid, and covered by a striped cuticula; 1 or 2 flagella present, at the base of which is a distinct mouth; no chlorophyll present: 14 genera.

Key to the genera of *Peranemidae* here described:

a_1 Body plastic.
b_1 Body elongate, attenuated forward.....1. PERANEMA
b_2 Body bottle-shaped.....2. URCEOLUS
a_2 Body rigid; two flagella.
b_1 Pharynx not deep.....3. ANISONEMA
b_2 Pharynx very deep.....4. ENTOSIPHON

Fig. 39
Peranema trichophorum (Conn).

1. **PERANEMA** Dujardin. Body tapers from behind forward and very plastic, with a spirally striated cuticula and a single flagellum, the tip of which vibrates when the animal moves: 1 species.

P. trichophorum (Ehrenberg) (Fig. 39). Length .08 mm.: in fresh water.

2. **URCEOLUS** Mereschkowski. Body spherical or ovate with a neck from which the flagellum emerges: 1 species.

U. cyclostomus (Stein). Length .03 mm.: in fresh water.

Fig. 40
Entosiphon sulcatum (Conn).

3. **ANISONEMA** Dujardin. Body ovate and compressed with striated cuticula and a lateral groove; 2 flagella, 1 of which trails behind: 3 species; in fresh and salt water.

A. vitreum Duj. Body transparent and with longitudinal furrows; length .05 mm.

4. **Entosiphon** Stein. Body ovate, with 2 flagella of nearly equal length, one of which trails behind, a deep ventral furrow and a very deep pharynx: 2 species.

E. sulcatum St. (Fig. 40). Length .02 mm.: in fresh and salt water.

Order 8. PHYTOFLAGELLIDA.

Flagellates which include most of those forms with holophytic or saprophytic nutrition, and are often classed as plants; most of them are enclosed in a cellulose shell or jelly; yellow, green or brown chromatophores usually present; very many are colonial: 4 suborders.

Key to the suborders of *Phytoflagellida* here described:

a_1 Yellow chromatophores usually present.....1. Chromomonadina
a_2 Green chromatophores usually present.
b_1 Mostly non-colonial; 2 or 4 flagella.....2. Chlamydomonadina
b_2 Colonial; 2 flagella.....3. Volvocina

Suborder 1. CHROMOMONADINA.

Flagellates with a delicate cuticula and often somewhat amœboid, which are usually enclosed in a shell or jelly, and are often colonial; yellowish or bluish chromatophores and 1 or 2 flagella present: 2 families.

Key to the families of *Chromomonadina:*

a_1 Color yellowish; no pharynx present.....1. Chrysomonadidae
a_2 Color blue, green or brown, or colorless; deep pharynx present.
2. Cryptomonadidae

Family 1. CHRYSOMONADIDAE.

Body usually with a shell or in a jelly, with 1 or 2 flagella and always with 1 or 2 yellowish chromatophores, and with or without eye-spots; nutrition usually holophytic: 15 genera.

Key to the genera of *Chrysomonadidae* here described:

a_1 Body in a shell which it does not fill.....1. Dinobryon
a_2 Body in a shell which fits it closely.
b_1 One flagellum.....2. Mallomonas
b_2 Two flagella.
c_1 Flagella of equal length.....3. Synura
c_2 One flagellum long, one short; colonial.....4. Uroglena

1. **Dinobryon** Ehrenberg. Free-swimming branched colonies, each individual of which is in a transparent cup-shaped shell which springs from just inside the opening of the shell next behind it; 2 flagella of unequal length, 1 or 2 yellowish or brownish chromatophores, and an eye-spot present: 3 species; in fresh water.

D. sertularia Ehr. (Fig. 41). Shell .04 mm. long: in fresh water, often in great quantities; sometimes fouls the water in reservoirs and ponds.

2. **Mallomonas*** Perty. Free-swimming and solitary, with closely fitting reticulated oval shell bearing long spines; 2 yellowish chromatophores; without eye-spot; 1 flagellum: several species in fresh water, which may produce an odor and injure water supplies.

M. punctifera (Ehrenberg). Spines all over shell; length .035 mm.

3. **Synura** Ehrenberg. Swimming spherical colonies of about 50 radially arranged individuals; each individual with 2 flagella, 2 brown chromatophores, eye-spots and sometimes spinose: 1 species.

S. uvella Ehr. (Fig. 42). Length of individual .03 mm.: in fresh water.

4. **Uroglena** Ehrenberg. Swimming spherical colonies composed of many individuals in a jelly; individual pear-shaped, with 2 unequal

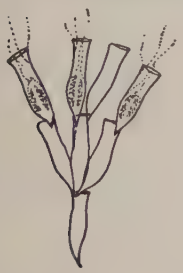

Fig. 41

Fig. 42

Fig. 43

Fig. 41—*Dinobryon sertularia* (Conn). Fig. 42—*Synura uvella* (Conn). Fig. 43—*Uroglena americana* (Calkins).

flagella, 2 yellow chromatophores, and an eye-spot: 2 species; in fresh water.

U. americana Calkins (Fig. 43). Length of individual .006 mm.: the cause of the fishy taste of the water in some reservoirs.

Family 2. CRYPTOMONADIDAE.

Body with a firm cuticula and not amœboid; 2 equally long flagella, at the base of which is a long pharynx extending to the middle of the body; 2 chromatophores present or absent: 3 genera.

Key to the genera of *Cryptomonadidae:*

a_1 Without chromatophores.
  b_1 A row of highly refractive bodies in forward part of body . . . 1. Cyathomonas
  b_2 Without such bodies . . . . . 2. Chilomonas
a_2 With chromatophores . . . . . 3. Cryptomonas

* See "Note on the Vertical Distribution of Mallomonas," by G. C. Whipple and H. N. Parker, Am. Nat., Vol. 33, p. 485, 1899.

1. **Cyathomonas** Fromentel. Body colorless, ovoid, flattened, with obliquely truncated forward end, with 2 flagella of nearly equal length; parallel with the anterior border is a row of highly retractile bodies: 1 species.

C. truncata (Fresenius) (Fig. 44). Length .023 mm.: in fresh water and infusions.

2. **Chilomonas** Ehrenberg. Body colorless, oval, compressed; forward end obliquely notched, with two equally long flagella: 2 species; in fresh water and infusions.

Fig. 44

Fig. 45

Fig. 46

Fig. 44—*Cyathomonas truncata* (Conn). Fig. 45—*Chilomonas paramecium* (Conn). Fig. 46—*Chlamydomonas pulvisculus* (Conn).

C. paramecium Ehr. (Fig. 45). Body ellipsoid; length .03 mm.: very common.

3. **Cryptomonas** Ehrenberg. Like *Chilomonas,* but with 2 green or brown chromatophores: 2 species; in fresh and salt water.

C. ovata Ehr. Length .03 mm.: in fresh water, to which it may give a fishy taste.

Suborder 2. CHLAMYDOMONADINA.

Body green in color with 2 or 4 flagella and usually a firm cuticula or shell within which division takes place: 2 families.

Family CHLAMYDOMONADIDAE.

Cuticula very delicate with no large pores: 7 genera.

1. **Chlamydomonas*** Ehrenberg. Body spherical to cylindrical with 2 flagella and an eye-spot, a delicate shell, prominent chromatophores and 2 contractile vacuoles: about 6 species; in fresh water.

C. pulvisculus Ehr. (Fig. 46). Body spherical, about .02 mm. in diameter: in fresh water, to which it gives an oily flavor.

2. **Spondylomorum** Ehrenberg. Colony of 16 cells in 4 alternating rows, each cell with 4 flagella: 1 species.

S. quaternarium Ehr. Diameter of colony .05 mm.: in fresh water.

3. **Polytoma** Ehrenberg. Body ellipsoid with a delicate shell and 2 flagella, colorless, occasionally with an eye-spot; 2 contractile vacuoles;

* See "Chlamydomonas and Its Effect on Water Supplies," by G. C. Whipple, Trans. Am. Micro. Soc., Vol. 21, p. 97, 1900.

reproduction by division into 4 or 8 cells, which remain in the shell and then become free: 2 species.

P. uvellum Ehr. (Fig. 47). Length .02 mm.: in fresh water.

Fig. 47—*Polytoma uvellum* (Conn).

Suborder 3. VOLVOCINA.

Colonial flagellates, the individual cells of which have each 2 flagella, an eye-spot and green chromatophores, and are imbedded in a common cellulose jelly; reproduction sexual and asexual: 7 genera, all represented in America; in fresh water.

Key to the genera of *Volvocina:*

a_1 Colony in form of a plate.
  b_1 Flagella on one side only of colony.
    c_1 Colony squarish ..... 1. Gonium
    c_2 Colony round with a spheroid envelope ..... 2. Stephanosphæra
  b_2 Flagella on both sides ..... 5. Platydorina
a_2 Colony spherical or ellipsoidal.
  b_1 Colony microscopic.
    c_1 Cells crowded, reaching center of colony ..... 3. Pandorina
    c_2 Cells not thus crowded.
      d_1 Cells alike in size ..... 4. Eudorina
      d_2 Anterior cells small, posterior ones large ..... 6. Pleodorina
  b_2 Colony not microscopic and composed of a large number of cells ... 7. Volvox

1. Gonium O. F. Müller. Colony of few and similar individuals forming a squarish plate with the flagella on one face only; asexual reproduction by repeated division of all the cells, each forming a new colony; sexual reproduction the result of the conjugation of pairs of similar individuals, the zygotes thus formed, after a resting stage, each developing into a colony: 2 species, 1 American; in fresh water.

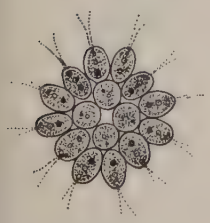

Fig. 48
Gonium pectorale (Doflein).

G. pectorale O. F. Mül. (Fig. 48). Colony consists of 16 cells and .06 mm. in diameter: cosmopolitan.

2. Stephanosphæra Cohn. Colony consisting of 4 or 8 cells arranged in a ring which is surrounded by a large rounded envelope of which the cells form the equator; reproduction as in *Gonium:* 1 species.

S. pluvialis Cohn. Envelopes up to .06 mm. in diameter.

3. Pandorina Bory de Vincent. Colony more or less spherical, composed of 16 or 32 crowded cells which reach the center and are surrounded by a lamellate envelope; reproduction as in *Gonium,* except that the conjugating cells may differ slightly in size: 1 species.

P. morum Bory. (Fig. 49). Colony up to .09 mm. in diameter: cosmopolitan.

4. **Eudorina** Ehrenberg. Colony more or less spherical, composed usually of 32 (occasionally of 16 or 64 cells) which are not close together and do not reach the center, and are surrounded by an envelope; asexual reproduction as in *Gonium;* at certain times sexual colonies appear, the female being like the ordinary colony, the male colony consisting of long, spindle-like cells which become free and unite with the female cells forming the zygotes: 2 species.

Fig. 49
Pandorina morum (Conn).

E. elegans Ehr. (Fig. 50). Colony about .15 mm. in diameter: cosmopolitan.

5. **Platydorina*** Kofoid. Colony flattened, horseshoe-shaped, composed of 16 or 32 cells with the flagella on both faces on alternate cells which are alike; asexual reproduction as in *Gonium;* sexual reproduction not observed: 1 species.

P. caudata Kofoid (Fig. 51). Colony about .15 mm. long and .13 mm. wide; posterior end of envelope with 3 or 5 tails: Illinois.

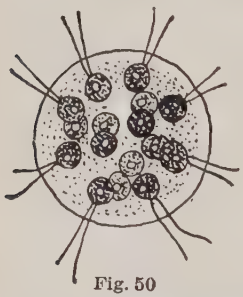

Fig. 50

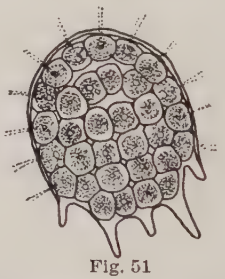

Fig. 51

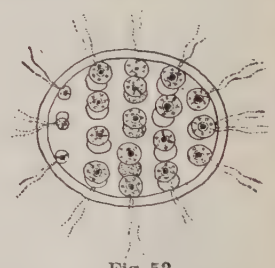

Fig. 52

Fig. 50—*Eudorina elegans* (Jordan and Kellogg). Fig. 51—*Platydorina caudata* (Kofoid). Fig. 52—*Pleodorina illinoisensis* (Kofoid).

6. **Pleodorina** Shaw. Colony more or less spherical, composed of 16 to 128 cells, certain of which are reproductive and the rest vegetative, the former being twice the size of the latter, and posterior in position; asexual reproduction as in *Gonium;* sexual reproduction not observed: 2 species; both in America.

P. californica Shaw. Cells 64 or 128, half of which are vegetative: California.

P. illinoisensis† Kofoid (Fig. 52). Cells 32, rarely 16 or 64, 4 of which are vegetative, .12 mm. in diameter: Illinois.

* See "On Platydorina," etc., by C. A. Kofoid, Bull. Ill. St. Lab., Vol. 5, p. 419, 1899.

† See "On Pleodorina Illinoisensis," etc., by C. A. Kofoid, Ill. St. Lab., Vol. 5, p. 273, 1898.

7. **Volvox*** L. Colony forms a hollow sphere of large size and composed of hundreds or thousands of cells connected by protoplasmic threads, and not differing in size; asexual reproduction by so-called parthenogonidia which are cells in the center of the colony (1 to 9 in number), which form there by repeated division daughter-colonies; at certain times sexual cells appear, the androgonidia and gynogonidia, which retire to the center of the colony where the latter are fertilized by the former and after a resting period the zygotes develop into new colonies: several species; in all parts of the world.

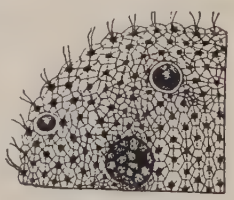

Fig. 53—*Volvox globator* (Shaffer).

V. globator L. (Fig. 53). Colony of 1,500 to 22,000 cells and up to 1.2 mm. in diameter; protoplasmic threads may contain chromatophores: cosmopolitan.

V. aureus Ehrenberg (*V. minor* Stein). Colony of 200 to 4,000 cells and up to .85 mm. in diameter; protoplasmic threads contain no chromatophores: cosmopolitan.

Subclass 2. DINOFLAGELLIDIA.†

Flagellates in most cases with a shell, around the equator of which is a transverse groove in which lies a flagellum; a second flagellum is also in most cases present, which may spring from a second and vertical groove; body sometimes colored by chromatophores: 3 orders.

Key to the orders of *Dinoflagellidia* here described:

a_1 No transverse groove; 2 flagella at forward end.....1. Adinida
a_2 Two grooves, a transverse and a longitudinal.....2. Diniferida

Order 1. ADINIDA.

Body without groove; 2 flagella at the forward end; shell composed of a right and a left half: 2 genera.

1. Exuviella Cienkowsky. Body ovoid, shells compressed and composed of right and left valves; 2 brown chromatophores present: 5 species; marine.

* See "New Forms of Volvox," by J. H. Powers, Trans. Am. Mic. Soc., Vol. 27, p. 123. "Light Reactions in Lower Organisms—II Volvox," by S. O. Mast, Jour. Comp. Neur. and Psy., Vol. 17, p. 99, 1907. "Le Volvox," by C. Janet, 1912.

† See "New Species of Dinoflagellates," by C. A. Kofoid, Bull. Mus. Com. Zool., Vol. 50, p. 163, 1907. "Dinoflagellata of the San Diego Region," by same, Univ. of Cal. Pub. Zool., Vol. 3, p. 299, 1907.

E. lima (Ehrenberg) (Fig. 54). Anterior border of both shells slightly indented; length .04 mm.; slow of movement: at Woods Hole.

Order 2. DINIFERIDA.

Two grooves present, a transverse and a longitudinal: 2 families.

Key to the families of *Diniferida:*

a_1 Transverse groove near middle of body.....1. Peridinidae
a_2 Transverse groove above the middle.....2. Dinophysidae

Family 1. PERIDINIDAE.

Transverse groove medium; longitudinal groove short; shell, when present, composed of plates or not; plates either equatorial (bordering the transverse furrow), apical, or antiapical, while a rhombic plate may extend from the transverse furrow to the apex: about 4 genera.

Key to the genera of *Peridinidae:*

a_1 With shell.
  b_1 Reticular markings on shell.
    c_1 Anterior part of shell with 7 equatorial and 1 rhombic plates. 1. Peridinium
    c_2 Anterior part of shell with 3 equatorial and no rhombic plates. 2. Ceratium
  b_2 No markings on shell.....3. Glenodinium
a_2 Without shell.....4. Gymnodinium

1. Peridinium* Ehrenberg. Body globular or elongate; shell with distinct transverse groove, which may be spiral and with about 20 plates: 9 species, fresh and salt water; many species are reddish in color and may be in sufficient numbers to color the sea.

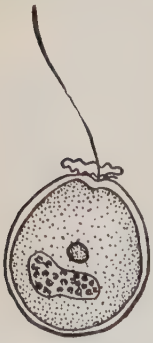

Fig. 54—*Exuviella lima* (Calkins).

P. digitale Pouchet (Fig. 55). Shell with large pits and with oblique furrow, 1 posterior and 2 anterior spines; length .06 mm.: Woods Hole; marine; common.

P. divergens Ehr. Shell spherical, tapering posteriorly, with 2 large spines anteriorly; length .07 mm.: Woods Hole; marine; common.

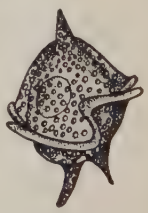

Fig. 55 *Peridinium digitale* (Calkins).

2. Ceratium† Schrank. Body a flattened sphere with 3 long projections; transverse groove either spiral or circular; longitudinal groove usually wide; shell reticulate or striped and composed of 10 plates; color usually green or brown: numerous species; in fresh and salt water.

* See "Peridinium and the 'Red Water' in Narragansett Bay," by A. D. Mead, Sci. N. S., Vol. 8, p. 707, 1898.

† See "Mutations in Ceratium," by C. A. Kofoid, Bull. Mus. Comp. Zool., Vol. 52, p. 213, 1909.

C. tripos Ehrenberg (Fig. 56). Body triangular with 1 very long and 2 short curved projections; length .29 mm.: Woods Hole; marine; common.

C. fusus Ehr. Animal very elongate, due to presence of 2 long projections in the same line; length .28 mm.: Woods Hole; marine; common.

3. **Glenodinium** Stein. Small globular forms with a transverse

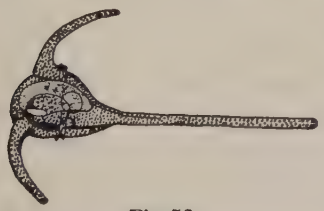

Fig. 56

Fig. 57

Fig. 58

Fig. 56—*Ceratium tripos* (Calkins). Fig. 57—*Glenodinium compressum* (Calkins). Fig. 58—*Gymnodinium gracile* (Calkins).

groove on anterior half and a short longitudinal one; shell soft and structureless and without markings: 6 species; in fresh and salt water.

G. compressum Calkins (Fig. 57). Body ovoid, compressed, with deep transverse and longitudinal grooves; hinder end often pointed and this point becomes attached; length .04 mm.: Woods Hole.

4. **Gymnodinium** Ehrenberg. Body without shell and spherical, sometimes pointed or flattened: 8 species; in fresh and salt water.

G. gracile Bergh (Fig. 58). Transverse groove in anterior half; longitudinal groove long; color brown; length .06 mm.: Woods Hole; marine.

Family 2. DINOPHYSIDAE.

Transverse groove near upper end of body, its edges as well as edge of the longitudinal groove being usually produced into characteristic ledges.

1. **Amphidinium** Claparède and Lachmann. Body ovoid and flattened; longitudinal groove extending from hinder end to transverse groove near forward end; shell absent; color, brown or green: 2 species; in fresh and salt water.

Fig. 59

Amphidinium operculatum (Calkins).

A. operculatum Cl. and Lach. (Fig. 59). Length .04 mm.: Woods Hole.

Subclass 3. CYSTOFLAGELLIDIA.

Marine flagellates of large size with a parenchymatous protoplasm: several genera.

Noctiluca Suriray. Body spherical and 1 mm. or less in diameter, with a median groove in which lies a large feeler and a small flagellum, as well as the mouth; single nucleus present; reproduction by division and by spore-formation: 1 species; marine.

N. miliaris Sur. In the Atlantic and Pacific Oceans; often so plentiful that the sea is colored red by day and glows by night with an intense phosphorescent light.

Class 3. SPOROZOA.*

Parasitic protozoans which live in the cells, tissues, and open spaces of other animals. The body is usually bounded by a thick cuticula; it has no external openings or contractile or gastric vacuoles, and in most cases but one nucleus. In the adult condition there are no organs of locomotion, although the animals have often the power of sluggish movement. Being entoparasites, all *Sporozoa* absorb food in a fluid or gaseous form through the outer surface of the body. Reproduction is carried on through the medium of spore formation, which usually follows encystment, the reproductive processes being in many forms very complex. Simple division does not occur. The *Sporozoa* are very widely distributed, living as parasites in every class of animals from *Protozoa* to *Vertebrata:* they are often the cause of disease both in man and the lower animals. The class contains two subclasses and about 400 known species, besides about as many uncertain species.

Key to the subclasses of *Sporozoa:*

a_1 Sporozoa in which spore formation ends the individual life, including the great majority of the class.....1. Telosporidia
a_2 Sporozoa in which the entire cell does not form spores but sporocysts are formed during life.....2. Neosporidia

Subclass 1. TELOSPORIDIA.

In these *Sporozoa* the individual life ends with spore formation, the entire cell forming spores: 3 orders.

Key to the orders of *Telosporidia:*

a_1 Parasitic as adults in the open spaces and organs of the host..1. Gregarinida
a_2 Parasitic in the solid tissues and not the open spaces.....2. Coccidiida
a_3 Parasitic in the blood of vertebrates.....3. Hæmosporidiida

Order 1. GREGARINIDA.

Usually elongate *Sporozoa* with a thick cuticula and a distinct nucleus; life history includes two stages, an attached stage, when the animals are known as cephalonts, and a detached and sporulating stage,

* See "Sporozoa," by A. Labbé, Das Tierreich, 1899.

when they are called sporonts and live in the open spaces of the organ to the walls of which they have been attached; body in most cases made up of two or three parts (Fig. 65), the epimerite at the forward end, which is the organ of attachment of the cephalont and may be dropped by the sporont, and the body, which may be divided by a septum into the deutomerite which forms the bulk of the body and contains the nucleus and the protomerite which lies between it and the epimerite: about 300 species grouped in 2 suborders.

Key to the suborders of *Gregarinida:*

a_1 Gregarines with an epimerite, and with or without a septum between the deutomerite and protomerite.....1. CEPHALINA

a_2 Gregarines without epimerite and consisting of a single chamber.....2. ACEPHALINA

SUBORDER 1. CEPHALINA.

Gregarines possessing an epimerite at some stage of their life which is sunk into the walls of the organs of the host in which they live; body usually elongate, the animals being often in associated couples or groups arranged tandem, in which case the first individual is called the primite and the others the satellites: in arthropods as adults, especially in the intestine of myriapods, beetles and *Orthoptera;* 10 families and about 100 species.

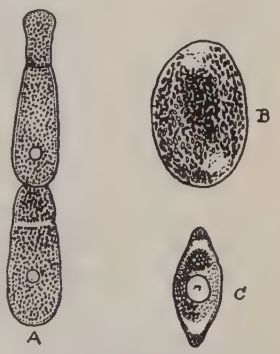

Fig. 60—*Gregarina blattarum* (Doflein). A, two individuals, each with protomerite and deutomerite; B, cyst; C, spore.

Key to the families of *Cephalina* here described:

a_1 Spore more or less ovoid.....1. GREGARINIDAE

a_2 Spore not ovoid.

b_1 Epimerite asymmetrical.....2. DACTYLOPHORIDAE

b_2 Epimerite symmetrical.

c_1 Spore symmetrical, animal solitary.....3. ACTINOCEPHALIDAE

c_2 Spore asymmetrical.

d_1 Spore crescent-shaped; animal solitary.....4. MENOSPORIDAE

d_2 Spore ovoid with polar thickening; in marine annelids..5. DOLIOCYSTIDAE

FAMILY 1. GREGARINIDAE.*

Individuals either associated, forming a chain with a septum separating each two individuals, or solitary; epimerite simple and symmetrical: 8 genera and about 35 species.

* See "List of the Polycystid Gregarines of the United States," by H. Crawley, Proc. Acad. Nat. Sci., Vol. 55, p. 41, 1903. "The Polycystid Gregarines of the United States," by H. Crawley, same, p. 632. "Movements of the Gregarines," same, Vol. 57, p. 89. "Study of Some Gregarines," etc., by M. C. Hall, Stud. from Zool. Lab. Univ. Neb., No. 77, 1907. "The Polycystid Gregarines of the United States," by H. Crawley, Proc. Acad. Nat. Sci., 1907, p. 220.

Key to the genera of *Gregarinidae* here described:

a_1 Individuals usually associated.....1. GREGARINA
a_2 Individuals usually solitary .....2. STENOPHORA

1. GREGARINA Dufour. Individuals usually associated; epimerite simple and small but varying in form, being conical or spherical; cysts spherical or ovoid, when ripe with long projections called sporoducts through which the spores emerge: about 20 species; in the digestive tract of insects.

Fig. 61
Gregarina achetae-abbreviatae (Crawley).

G. blattarum von Siebold (Fig. 60). Body elongate but somewhat irregular; cyst ovoid with long sporoducts; length about .5 mm.: in the intestine of the cockroach.

G. achetae-abbreviatae Leidy (Fig. 61). Deutomerite ellipsoidal or oval; protomerite hemispherical; animals solitary or in pairs; length .5 mm.: in the common cricket.

G. melanopli Crawley. Protomerite cubical or flattened; deutomerite more or less rectangular; length .37 mm.: in intestine of the grasshopper.

G. locustae-carolinae Leidy. Protomerite globular on which the epimerite appears as a small round knob; deutomerite globular; length .35 mm.: in intestine of the large grasshopper, *Dissosteira carolina.*

Fig. 62
Stenophora juli (Crawley).

2. STENOPHORA Labbé. Body large, ovoid or elongate; cyst without sporoducts; protomerite small: 4 species.

S. juli Frantzius (Fig. 62). With the characters of the genus; protomerite often conical: very common in the intestine of *Julus.*

FAMILY 2. DACTYLOPHORIDAE.

Epimerite asymmetrical and irregular, with digitiform processes: 5 genera.

Fig. 63

Fig. 64

Fig. 63 — *Echinomera hispida* (from Bronn). Fig. 64— *Amphoroides fontariae* (Crawley).

1. ECHINOMERA Labbé (*Echinocephalus* Schneider). Body ovoid and massive; epimerite conical with the apex excentric and varied in form: 1 species.

E. hispida (Schneider) (Fig. 63). Deutomerite eight or ten times as long as the other two divisions; animal very active: common in gut of *Lithobius.*

2. TRICHORHYNCHUS Schneider. Protomerite cylindrical or truncated with a long rostrum: 1 species.

T. pulcher Schneider. In the intestine of *Scutigera;* length .07 mm.

Family 3. ACTINOCEPHALIDAE.

Solitary animals with symmetrical epimerite; spores symmetrical and spindle-shaped: 17 genera and about 27 species.

1. **Amphoroides** Labbé. Epimerite simple and regular, with a conical point; protomerite very short and cup-like; spores biconical: 2 species.

A. fontariae Crawley (Fig. 64). Deutomerite a long oval, hinder end being always blunt; protomerite circular or pentagonal; length .13 mm.: in diplopods of the family *Polydesmidae;* often numerous.

2. **Asterophora** Léger. Epimerite mucronate and elongate; protomerite usually larger than the deutomerite: 3 species.

A. cratoparis Crawley (Fig. 65). Deutomerite lanceolate, terminating bluntly; protomerite round with a conical projection in front; epimerite small, consisting of a number of ribs; length .5 mm.: in curculionid beetles.

Fig. 65
Asterophora cratoparis (Crawley).

Family 4. MENOSPORIDAE.

Fig. 66
Hoplorhynchus actinotus (Crawley).

Epimerite large, joined by a long neck with the protomerite; spores crescent-shaped: 2 genera.

Hoplorhynchus Carus. Animals solitary; elliptical in shape; epimerite with 6 to 8 long marginal teeth: 2 species.

H. actinotus (Leidy) (Fig. 66). Deutomerite conical with a pointed hinder end; protomerite small, tending to fuse with the deutomerite; epimerite long, with a large spreading front end; length .5 mm.: in *Scolopocryptops,* a diplopod.

Family 5. DOLIOCYSTIDAE.

Deutomerite not separate from protomerite: spore ovoid, with polar thickening: 1 genus.

Doliocystis Léger. With the characters of family: 6 species.

D. rhyncoboli Crawley. Deutomerite long, tapering to the hinder end; protomerite and epimerite small: in the intestine of *Rhynchobolus americanus.*

Suborder 2. ACEPHALINA.

No epimerite present, the body consisting of a single chamber; spore spindle-shaped: about 10 genera and numerous species, which live principally in the body cavity of the host and the organs connected with it.

Fig. 67—*Monocystis lumbrici* (from Bronn). A, single individual; B, a spore; C, a cyst.

Monocystis Stein. Body ovoid or elongate, sometimes with long cuticular filaments; individuals mostly solitary: about 10 species.

M. lumbrici (Henle) (*M. agilis* Stein) (Fig. 67). Length .2 mm.: in intestine, genital organs and cœlom of the earthworm; common.

M. clymenellae* Porter. In the body wall of *Clymenella torquata.*

Order 2. COCCIDIIDA.

Sporozoa of spherical or ovoid shape without a free stage, which live imbedded in the solid tissues of the host, usually as intracellular parasites; reproduction by sporulation with an alternation or generations: 5 families and 70 species.

Eimeria Schneider (*Coccidium* Leuckart). Cyst ovoid, each on sporulation forming 4 sporoblasts, each of which produces 2 spores: 13 species.

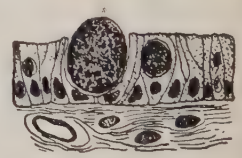

Fig. 68—*Eimeria stiedae* (Doflein). An infected intestinal epithelium.

E. stiedae (Lindemann) (*E. cuniculi* Rivolta) (Fig. 68). In the liver and other organs of rabbits and other animals, also in the human liver; length of cyst .04 mm.

Order 3. HÆMOSPORIDIIDA.

Sporozoa parasitic in the blood of vertebrates, with or without a change of hosts; reproduction occurs by asexual spore-formation usually in the body of some other animal where conjugation takes place followed by pseudosexual spore-formation: about 4 genera.

1. **Plasmodium** Marchiafava and Celli. An intra-corpuscular parasite in mammalian blood corpuscles where it finally breaks up into about 12 asexual spores (merozoites) which are often grouped about a central

* See "Two New Gregarinida," by J. F. Porter, Jour. Morph., Vol. 14, 1908.

body composed of melanin pigment, and then enter other corpuscles; spore-formation occurs every seventy-two hours or oftener, and is accompanied by a chill in the patient followed by a fever; if the blood is drawn into the intestine of a mosquito of the genus *Anopheles* certain of these spores produce flagellate individuals (*microgametes*), and others produce rounded spores (*macrogametes*); these two conjugate, and motile individuals (*zygotes*) are the result, which penetrate the intestinal mucous membrane and form large cysts on its outer surface; here they sporulate and develop finally into long, slender sporozoites which migrate into the body cavity and then into the salivary glands of the mosquito and are injected with the saliva into the blood of the next person the mosquito bites: 3 species.

Fig. 69 — *Plasmodium malariae* (Doflein). The 6 circles represent blood corpuscles into which the parasite has entered (A), where it grows until it fills the corpuscle (E) and finally breaks up into about 8 spores (F), the whole process occupying 72 hours.

P. malariae (Laveran) (Fig. 69). The cause of quartan malaria, in which the chill and fever occur every seventy-two hours.

P. vivax Grassi and Feletti. The cause of the tertian malaria in which the chill and fever occur every forty-eight hours.

P. falciparum Welch. The cause of pernicious or autumnal malaria in which the chill and fever occur every twenty-four hours, or irregularly.

Fig. 70 — *Babesia bigemina* (Doflein). The 8 circles represent blood corpuscles containing the parasite.

2. Babesia Starcovici (*Pyrosoma* Smith and Kilbourne; *Piroplasma* Patton). An intracorpuscular parasite of mammalian blood-corpuscles, without melanin pigment; transmission by the bite of ticks in whose intestine the pseudosexual processes occur: many species.

B. hominis (Manson). The cause of Rocky Mountain spotted fever in man, the tick involved being *Dermacentor venustus*.

B. bigemina (Smith and Kilb.) (Fig. 70). The cause of Texas fever in cattle, the tick involved being *Margaropus* (*Boophilus*) *annulatus*.

Subclass 2. NEOSPORIDIA.

Sporozoa which form sporocysts throughout life, the entire cell not being used in the formation of spores: 4 orders.

Key to the orders of *Neosporidia* here described:

a_1 In the organs of fishes and insects.....1. Myxosporidiida
a_2 In the muscle fibres of vertebrates.....2. Sarcosporidiida

Order 1. MYXOSPORIDIIDA.*

Sporozoan parasites which occur in various organs of fishes, insects, and other animals; body amœboid or spherical and multinuclear; sporulation gives rise to sporoblasts in each of which one to several spores develop: 4 families, including some dangerous parasites, one of which is *Glugea bombysis,* the silk-worm parasite, which in thirteen years previous to 1867 caused a loss in France of one billion francs.

Family MYXOBOLIDAE.

Parasites of fishes rarely found in the amœboid form, but usually as cysts filled with spores in which are vacuoles which are stained reddish brown by iodine: 3 genera.

Myxobolus Bütschli. Spores ovoid or elliptical: about 40 species.

M. lintoni Gurley. In all the tissues of *Cyprinodon variegatus.*

Order 2. SARCOSPORIDIIDA.

Sporozoan parasites in the muscle fibres of vertebrates; body elongate forming cysts with a double membrane, in which are spores: 1 genus.

2. **Sarcocystis** Lankester. Elongated *Sporozoa* living in the muscle fibres of the pig, sheep, rat, and other animals: about a dozen species.

S. miescheriana (Kühn) (Fig. 71). Length of cyst 3 mm.: in the pig.

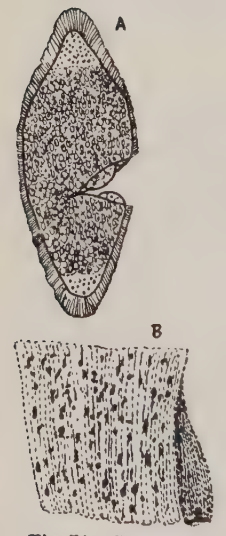

Fig. 71—*Sarcocystis miescheriana* (Doflein). A, a cyst; B, a piece of pork containing cysts.

Class 4. INFUSORIA.†

The *Infusoria* are distinguished by their definite body form, the outer surface of the body being bounded by a firm cuticula, and by the possession of cilia. These cilia are short hair-like projections of the ectosarc through the cuticula, and in the various species may appear as rapidly vibrating locomotory organs, or may be united to form tentacles, spines, membranes, or sucking tubes. The ectosarc is often highly specialized. In many forms it contains large numbers of defensive organs called trichocysts, which are minute rods lying perpendicular to

* "The Myxosporidia or Psorosperms of Fishes and the Epidemics Produced by Them," by R. R. Gurley, Bull. U. S. Fish. Com., Vol. II, 1893.

† See "A Manual of the Infusoria," by W. S. Kent, 1881. "A Preliminary Contribution towards a History of the Fresh-water Infusoria of the United States," by A. C. Stokes, Jour. Trenton Nat. Hist. Soc., Vol. 1, p. 71, 1888.

the surface which may be shot out into the water. In a few forms (*Vorticella*) nettle organs are present. The ectosarc often contains muscle ridges called myonemes, which appear as parallel longitudinal or spiral lines, and in a few cases (*Stentor*) striated muscle fibrillae are present. The entosarc is more fluid than the ectosarc and is granular and contains a variety of specialized structures. Chief of these are the nuclei, of which two kinds are present, the micronucleus and the macronucleus. The latter is of large size and often branched or irregular in shape, and is supposed to be vegetative in function. The very much smaller micronucleus, of which more than one may be present, lies alongside the macronucleus and is chiefly concerned with reproduction and conjugation. The entosarc also contains one or more contractile vacuoles and food vacuoles. The former have a definite position in the body and serve to eliminate the water taken in with the food vacuoles together with the excretory wastes. The food vacuoles are globules of water which are taken into the entosarc together with the food.

The food of *Infusoria* consists of organic particles of all sorts: some live principally on animal food, some on plant food, many are scavengers, and a few are parasitic. In all, with the exception of certain parasitic forms, mouth and gullet are present: an oral groove may lead to the mouth. The anus is usually a temporary opening.

The *Infusoria* reproduce by division, the animal in most cases dividing into two equal parts. In some forms division takes the form of budding. Conjugation takes place in all *Infusoria*. The two conjugating individuals fuse, in most cases temporarily by the ectosarc of the mouth region, and an interchange of micronuclear substance takes place. The macronucleus disintegrates in each animal while the micronucleus divides several times. The products of these divisions disintegrate, with the exception of a single one, which divides again. Of the two micronuclei thus obtained in each of the conjugating individuals, one migrates across to the other individual and fuses with the micronucleus remaining there. This fusion micronucleus then divides and a portion of it enlarges to form a new macronucleus. Where more than one micronucleus is present, it is probable that this process goes on with all of them. All *Infusoria* encyst themselves at certain times, in which condition they may be carried by the wind long distances. The *Infusoria* are found in both fresh and salt water. The name originated with Ledermüller in 1763 and was at first applied to all minute organisms which may appear in infusions. Only in modern times has its use been confined to protozoans. The class contains about 1,200 species grouped in 2 subclasses.

Key to the subclasses of *Infusoria:*

a_1 Cilia present ..... 1. CILIATA
a_2 No cilia present in the adult, but long sucking tubes ..... 2. SUCTORIA

SUBCLASS 1. CILIATA.

Protozoa with cilia and usually with a definite mouth and gullet: 4 orders with about 1,000 species, of which about 400 are marine.

Key to the orders of *Ciliata:*

a_1 Cilia usually, but not always, present on all parts of the body.
  b_1 Cilia all approximately of the same length ..... 1. HOLOTRICHIDA
  b_2 Mouth surrounded by an adoral zone of large cilia ..... 2. HETEROTRICHIDA
a_2 Cilia present on only a part of the body.
  b_1 Cilia confined to the ventral side ..... 3. HYPOTRICHIDA
  b_2 Cilia confined to one or more rings around the body ..... 4. PERITRICHIDA

ORDER 1. HOLOTRICHIDA.

Protozoa in which the cilia are usually evenly distributed over the body, with a tendency to arrange themselves in straight lines, which have often a spiral arrangement; in the vicinity of the mouth the cilia are often longer than elsewhere and in a few forms are confined to this region; trichocysts almost always present: 10 families.

Key to the families of *Holotrichida* here described:

a_1 Animals not parasitic.
  b_1 Mouth closed except when taking in food, and without undulating membrane.
    c_1 Mouth terminal or subterminal.
      d_1 Body usually oval or cylindrical ..... 1. ENCHELINIDAE
      d_2 Dorsal side arched; forward end often neck-like ..... 2. TRACHELINIDAE
    c_2 Body ovoid; mouth in middle or posterior region .... 3. CHLAMYDODONTIDAE
  b_2 Mouth always open and ventral with an undulating membrane around it or in the gullet.
    c_1 Oral groove absent or slightly developed.
      d_1 No equatorial zone of cilia ..... 4. CHILIFERIDAE
      d_2 Broad equatorial zone of cilia ..... 5. UROCENTRIDAE
    c_2 Long oral groove present.
      d_1 No undulating membrane along oral groove ..... 6. PARAMECIIDAE
      d_2 An undulating membrane along the oral groove ..... 7. PLEURONEMIDAE
a_2 Animals parasitic; mouth absent ..... 8. OPALINIDAE

FAMILY 1. ENCHELINIDAE.

Usually oval *Infusoria,* sometimes with a long slender forward portion, with a terminal mouth by which large objects are swallowed, food not being introduced in currents, as the gullet is never ciliated: about 18 genera; principally in fresh water.

Key to the genera of *Enchelinidae* here described:

a_1 Cilia cover whole body.
  b_1 Body not covered with rectangular plates.
    c_1 Body not elongate and contractile.
      d_1 Gullet absent or short.
        e_1 Posterior bristle not present.
          f_1 Mouth terminal; body ovoid.....1. HOLOPHRYA
          f_2 Mouth subterminal; body with slight neck.....2. ENCHELYS
        e_2 Posterior bristle present.....3. UROTRICHA
      d_2 Gullet long and lined with a membrane.....4. PRORODON
    c_2 Body elongate and contractile.
      d_1 Body flask-shaped with contractile neck.....5. LACRYMARIA
      d_2 Body very long and contractile.....7. TRACHELOCERCA
  b_2 Body covered with rectangular plates.....6. COLEPS
a_2 Cilia confined to 1 or 2 girdles.
  b_1 Deep equatorial furrow present.....8. MESODINIUM
  b_2 No such furrow.....9. DIDINIUM

1. **HOLOPHRYA** Ehrenberg. Body striated, cylindrical or ovoid; ciliation uniform; no trichocysts: 6 species; in fresh and salt water.

Fig. 72

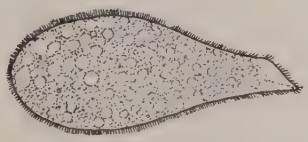

Fig. 73

Fig. 74

Fig. 72—*Holophrya discolor* (from Bronn). Fig. 73—*Enchelys pupa* (Conn). Fig. 74—*Urotricha fareta* (Conn).

H. discolor Ehr. (Fig. 72). Body ovoid; length .04 mm.: in standing water.

2. **ENCHELYS** O. F. Müller. Anterior end somewhat elongated and truncated with subterminal mouth: 5 species; in fresh and salt water.

E. pupa Ehrenberg (Fig. 73). Body ovoid; length .08 mm.; color often greenish.

3. **UROTRICHA** Claparède and Lachmann. Like *Holophrya,* but with a bristle at hinder end: 2 species; in fresh water.

U. fareta Cl. and Lach. (Fig. 74). Springs with its bristle; length .02 mm.

4. **PRORODON** Ehrenberg. Body ovate or ellipsoid, with a long gullet lined by a membrane: 8 species; in fresh water.

P. griseus Claparède and Lachmann. Length .25 mm.: in standing water.

5. **LACRYMARIA** Ehrenberg. Body flask-shaped, with a contractile neck and spiral striations: 4 species; in fresh and salt water.

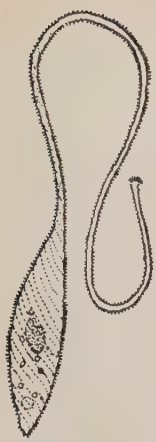

Fig. 75
Lacrymaria olor (Conn).

L. olor (O. F. Müller) (Fig. 75). Body extremely elastic, colorless or green; length without neck .2 mm.; neck may be much longer than body: in fresh water.

L. lagenula Claparède and Lachmann. Body flask-shaped, with a short conical neck which has a crown of longer cilia; length up to .16 mm.: in decaying marine and fresh-water algae.

6. Coleps Nitzsch. Barrel-shaped, rigid, with an armor composed of rectangular plates between which the cilia project: 3 species; in fresh water.

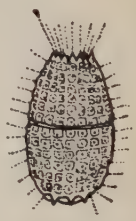

Fig. 76
Coleps hirtus (Conn).

C. hirtus Ehrenberg (Fig. 76). Gray or green; length .04 mm.: in swamps.

7. Trachelocerca Ehrenberg. Body very long, slender, and contractile: marine; 1 species.

T. phœnicopterus Cohn (Fig. 77). Length up to 1.7 mm.; with a four-sided mouth, which may not be seen: Woods Hole.

8. Mesodinium Stein. Body globular or conical, with a deep furrow around the middle from which spring one or more rows of cirri; 4 contractile tentacles in the mouth: 3 species; in fresh and salt water.

Fig. 77
Trachelocerca phœnicopterus (Calkins).

M. cinctum Calkins (Fig. 78). Cirri projecting forward number about 30: marine; Woods Hole.

9. Didinium Stein. Body cylindrical, with 1 or 2 girdles of cilia and with a horseshoe-shaped macronucleus; forward end a projecting cone with the mouth at the tip: 2 species; in fresh water.

D. nasutum* (O. F. Müller) (Fig. 79). Length .1 mm.: feeds on *Paramecium* and other large infusorians.

Family 2.
TRACHELINIDAE.

Dorsal side of body arched; mouth terminal or subterminal, usually at the end of a long neck: 6 genera.

Fig. 78

Fig. 79

Fig. 78 — *Mesodinium cinctum* (Calkins). Fig. 79 — *Didinium nasutum* (Mast).

* See "The Reactions of Didinium nasutum," etc., by S. O. Mast, Biol. Bull., Vol. 16, p. 91, 1909.

Key to the genera of *Trachelinidae* here described:

a_1 Distinct neck region.
  b_1 Mouth runs the length of the neck.
    c_1 Entire body uniformly ciliated.....1. AMPHILEPTUS
    c_2 Ventral surface only ciliated.....2. LIONOTUS
  b_2 Mouth at base of neck, which is very long.....4. DILEPTUS
a_2 No distinct neck region.....3. LOXOPHYLLUM

1. AMPHILEPTUS Ehrenberg. Body often curved, elongate, flattened, with a sharp neck-like forward end; no gullet: 3 species; in fresh and salt water.

A. gutta Claparède (Fig. 80). Macronucleus double; length .08 mm.

Fig. 80

Fig. 81

Fig. 80—*Amphileptus gutta* (Conn). Fig. 81—*Lionotus fasciola* (Calkins). Fig. 82—*Loxophyllum rostratum* (Conn).

Fig. 82

2. LIONOTUS Wrzesniowski. Body elongate, tapering to both ends, with a large hump; usually two macronuclei; flattened side only ciliated; anterior end neck-like: 6 species; in fresh and salt water.

L. wrzesniowskii Kent. Length .18 mm.: in fresh water.

L. fasciola (Ehrenberg) (Fig. 81). Body ellipsoid, hinder end conical; length up to .6 mm.: in fresh and salt water; Woods Hole; Cold Spring Harbor.

3. LOXOPHYLLUM Dujardin. Body flat, with a broad hyaline border; anterior projection slight, turned to the right; trichocysts often in papilla-like groups; nucleus often bead-like: in standing water; 4 species; in fresh and salt water.

L. rostratum Cohn (Fig. 82). Body elongate; length .15 mm.: in fresh water.

Fig. 83—*Dileptus anser* (Conn).

L. setigerum Quennerstedt. Body broad; 1 mm. long: in salt water.

4. DILEPTUS Dujardin. Body large, elongate, with a long contractile neck, at the base of which is the mouth; numerous contractile vacuoles; nucleus often bead-like: 2 species; in fresh and salt water.

D. anser (O. F. Müller) (Fig. 83). Body striated; length up to 1.5 mm.: among algae in fresh water.

Family 3. CHLAMYDODONTIDAE.

Ovoid or kidney-shaped *Infusoria* with the mouth usually some distance from anterior end; gullet specially modified to swallow food of large size: about 11 genera.

1. Nassula Ehrenberg. Body ovate or cylindrical; mouth between middle and anterior end; gullet armed with rods or with a membrane: 8 species; in fresh and salt water.

N. ornata Ehr. Body nearly circular, usually with brightly colored spots; gullet with rods; length .2 mm.: in fresh water.

N. macrostoma Cohn (Fig. 84). Body nearly circular, with brightly colored spots; gullet with a membranous lining; length .05 mm.: marine; Woods Hole.

2. Chilodon Ehrenberg. Body flattened, with convex dorsal side;

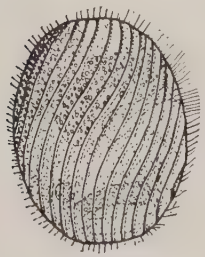

Fig. 84

Fig. 85

Fig. 86

Fig. 84—*Nassula macrostoma* (Calkins). Fig. 85—*Chilodon cucullulus* (Calkins). Fig. 86—*Frontonia leucas* (Calkins).

mouth at or in front of middle of body; gullet armed with rods: 6 species; in fresh and salt water.

C. cucullulus (O. F. Müller) (Fig. 85). Length .1 mm. or less; body ovoid; forward end bent to the left: in fresh and salt water.

Family 4. CHILIFERIDAE.

Mouth never behind the middle and always open, with an undulating membrane on the edge of it or in the slightly developed gullet: 9 genera.

Key to the genera of *Chiliferidae* here described:

a_1 Long ventral furrow leading back from the mouth.....1. Frontonia.
a_2 No such furrow.
b_1 Caudal bristle present.....3. Uronema
b_2 No bristle.
c_1 Body oval, symmetrical.....2. Colpidium
c_2 Body rounded dorsally, straight ventrally.....4. Colpoda

1. Frontonia Ehrenberg. Body large, ellipsoid or elongate and contractile and colorless, or green or brown, with mouth near forward

end and an undulating membrane in the gullet: 3 species; in fresh and salt water.

F. leucas Ehr. (Fig. 86). Body brown or black in color; length .3 mm. or more; a furrow extends back from the mouth: in fresh and salt water; Woods Hole.

2. **Colpidium** Stein. Body oval, the ventral side being incurved and the forward end smaller than the hinder; mouth central: 2 species; in fresh and salt water.

C. colpoda (Ehrenberg) (Fig. 87). Length .045 mm. or more: in fresh and salt water; common in infusions; Woods Hole.

3. **Uronema** Dujardin. Body minute and oval, with a long bristle at the hinder end; mouth near middle surrounded by membranes: 6 species; in fresh and salt water.

Fig. 87

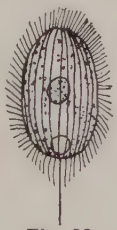

Fig. 88

Fig. 89

Fig. 87—*Colpidium colpoda* (Calkins). Fig. 88—*Uronema marinum* (Calkins). Fig. 89—*Colpoda cucullus* (Conn).

U. marinum Duj. (Fig. 88). Length .05 mm.: in fresh and salt water; in decaying vegetation; marine; Woods Hole.

4. **Colpoda** O. F. Müller. Body laterally compressed, with rounded dorsal and straight ventral surface; mouth toward forward end, surrounded by long cilia: several species; in fresh water, especially in hay infusions.

C. cucullus Mül. (Fig. 89). Body ellipsoidal; length .1 mm.: in fresh water; very common.

Family 5. UROCENTRIDAE.

Body barrel-shaped; mouth near the middle; a broad girdle of longer cilia around the body: 1 genus.

Urocentrum Nitzsch. Characters as above: 1 species; in fresh and salt water.

U. turbo (O. F. Müller) (Fig. 90). Length .06 mm.; swims with a whirling motion.

Family 6. PARAMECIIDAE.

Body elongate, with a long, deep, oral groove leading to the mouth which is in the middle or hinder part of the body: 1 genus; common in infusions and decaying organic matter.

Paramecium* O. F. Müller. Slipper-animalcules. Characters as above; trichocysts distinct; two contractile vacuoles: 4 species; in fresh and salt water.

P. aurelia Mül. (Fig. 91). Forward end rounded; hinder end bluntly pointed; length .15 mm.; 2 micronuclei: in fresh and salt water; common.

P. caudatum Ehrenberg (Fig. 92). Like *P. aurelia,* but somewhat larger and more pointed behind and with 1 micronucleus: in fresh water; commoner than the preceding.

Fig. 90

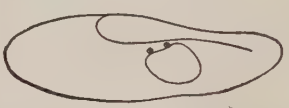

Fig. 91

Fig. 92

Fig. 90—*Urocentrum turbo* (Conn). Fig. 91 and Fig. 92—*Paramecium aurelia* and *P. caudatum* in outline (George T. Hargitt).

P. bursaria Ehr. Body wide, rounded, and obliquely truncate forward and pointed or rounded behind; usually bright green from the numerous green algae (*zoochlorellae*) in the ectosarc; length .12 mm.: in fresh water.

Family 7. PLEURONEMIDAE.

Body oval or ellipsoidal, with a long, deep oral groove leading to the mouth in hinder part of body; along the edge of this groove is a large undulating membrane: 5 genera.

Key to the genera of *Pleuronemidae* here described:

a_1 No caudal bristle.
  b_1 Hinder end acute.....1. Lembadion
  b_2 Hinder end rounded.....2. Pleuronema
a_2 Caudal bristle present.....3. Lembus

1. **Lembadion** Perty. Body oval, rigid, posterior end acute: 1 species.

L. bullinum Perty (Fig. 93). Length .05 mm.: in fresh water.

2. **Pleuronema** Dujardin. Body rigid, oval, and flattened; oral groove takes in a large part of the ventral surface and with a high, undulating membrane; cilia very long: 2 species; in fresh and salt water.

P. chrysalis (Ehrenberg) (Fig. 94). Moves by springs and by swimming; length .04 mm.: in fresh and salt water; in decaying vegetation.

* See "Races of Paramecium," by H. S. Jennings and G. T. Hargitt, Jour. Morph., Vol. 21, p. 495, 1910. "Two Thousand Generations of Paramæcium," by L. L. Woodruff, Arch. f. Prot. Vol. 21, p. 263, 1911. "Paramæcium aurelia and P. caudatum," by same, Jour. Morph., Vol. 22, 1911.

3. **Lembus** Cohn. Body elongate, with a long caudal bristle; mouth in the middle with the oral groove leading to it from the forward end: in decaying plants; 3 species; marine.

Fig. 93

Fig. 94

Fig. 95

Fig. 93—*Lembadion bullinum* (Conn). Fig. 94—*Pleuronema chrysalis* (Calkins). Fig. 95—*Lembus infusionum* (Calkins).

L. infusionum Calkins (Fig. 95). Body lancet-shaped, with a tapering anterior extremity; a row of contractile vacuoles extends from the hinder end forward; length .07 mm.: Woods Hole.

Family 8. OPALINIDAE.

Mouth absent; body oval or elongate: 6 genera, parasitic in the *Anura* and in worms and mollusks.

1. **Opalina*** Purkinje and Valentin. Elliptical *Infusoria* living parasitic in the rectum of frogs and toads; 13 species.

O. ranarum Pur. and Val. (Fig. 96). Body flattened; many contractile vacuoles; length .6 mm.: in frogs and toads.

Fig. 96
Opalina ranarum (Doflein).

2. **Anoplophrya** Stein. Body elongate: in the digestive tract of marine annelids and on the gills of crustaceans; occasionally free-swimming.

A. branchiarum St. Length .1 mm.; body flask-shaped: Woods Hole; free-swimming.

Order 2. HETEROTRICHIDA.

Body with uniform ciliation and an adoral zone along the oral groove consisting of cilia fused together to form membranelles: 7 families.

Key to the families of *Heterotrichida* here described:

a_1 Body not in a cup.
  b_1 Body not with a crown of long cirri.
    c_1 Body not funnel or trumpet-shaped.
      d_1 Body elongated.....1. Plagiotomidae
      d_2 Body usually oval with a triangular oral groove.....2. Bursariidae
    c_2 Body funnel or trumpet-shaped.....3. Stentoridae
  b_2 Body with a crown of long cirri.....4. Halteriidae
a_2 Body in a cup.....5. Tintinnidae

* See "Opalina," by M. M. Metcalf, Arch. f. Prot., Vol. 13, p. 195, 1909.

Family 1. PLAGIOTOMIDAE.

The oral groove extends from the forward end of the mouth, near the middle of the body; adoral zone along the left side of the groove; body elongate: 6 genera.

Key to the genera of *Plagiotomidae* here described:

a_1 Oral groove spiral.....1. Metopus
a_2 Oral groove straight.
b_1 Forward end acute and turned to the left.....2. Blepharisma
b_2 Body straight and worm-like.....3. Spirostomum

Fig. 97
Metopus sigmoides (Conn).

1. Metopus Claparède and Lachmann. Body cylindrical; oral groove extends spirally across the forward two-thirds of body; contractile vacuole at hinder end: 2 species; in fresh and salt water.

M. sigmoides (O. F. Müller) (Fig. 97). Length .13 mm.; body very contractile: in fresh water.

2. Blepharisma Perty. Forward end acute and turned to the left; hinder end rounded: several species; in fresh water.

B. undulans Stein (Fig. 98). Length .37 mm.; color red: in fresh water.

3. Spirostomum Ehrenberg. Body long, cylindrical, and worm-like, very contractile, with distinct spiral striations; nucleus bead-like; oral groove in about first third of body; contractile vacuole at hinder end: 2 species; in fresh and salt water.

Fig. 98
Blepharisma undulans (Conn).

S. teres Claparède and Lachmann (Fig. 99). Length .4 mm.; body tapers slightly at both ends; nucleus sometimes simple.

S. ambiguum (Bory de Vincent). Body 1 mm. long or more, and not tapering.

Fig. 99
Spirostomum teres (Conn).

Family 2. BURSARIIDAE.

Body usually oval and flattened, the oral groove being a triangular sunken area ending in the mouth; adoral zone on left edge of groove: 5 genera.

Key to the genera of *Bursariidae* here described:

a_1 Animals parasitic.....2. Balantidium
a_2 Animals not parasitic.
b_1 Body very broad.....1. Bursaria
b_2 Body cylindrical.....3. Condylostoma

1. **Bursaria** O. F. Müller. Body large, purse-shaped, obliquely truncate in front; nucleus long, ribbon-like: 1 species; in fresh water.

B. truncatella Mül. (Fig. 100). Length 1 mm. and more: often between fallen leaves in the water.

Fig. 100
Bursaria truncatella (Conn).

2. **Balantidium** Stein. Body spindle-shaped, with the oral groove at the apex: 4 species, parasitic in mammals, amphibians, and worms.

B. coli St. (Fig. 101). Length .12 mm.: in the large intestine of the pig and man, causing diarrhœa.

B. entozoon (Ehrenberg). Length .2 mm.: in the large intestine of frogs, toads, and salamanders.

3. **Condylostoma** Dujardin. Body rounded or cylindrical, tapering anteriorly with obliquely truncate forward end; nucleus bead-like: 2 species, in fresh and salt water.

C. patens (O. F. Müller) (Fig. 102). Length .4 mm.: width .10 mm.: fresh and salt water.

Fig. 101

Fig. 102

Fig. 103

Fig. 101—*Balantidium coli* (Doflein). Fig. 102—*Condylostoma patens* (Calkins). Fig. 103—*Stentor cæruleus* (Doflein).

Family 3. STENTORIDAE.

Body the shape of an elongated funnel and very contractile, the small end of which can be attached; large end truncate, the adoral zone passing around the edge; nucleus usually beaded: 2 genera; in fresh water.

Stentor* Oken. Fixed or free-swimming; when swimming body is contracted and ovate: 8 species; in fresh water.

S. cæruleus Ehrenberg (Fig. 103). Body blue; length .25 mm.

* See "Selection of Food in Stentor cæruleus (Ehr.)," by A. A. Schaeffer, **Jour. Exp. Zool., Vol. 8, p. 839, 1910.**

S. polymorphus (O. F. Müller). Body usually green from the presence of algae (*zoochlorellae*) but sometimes colorless; length 1 mm.: sometimes very abundant on water plants.

S. rœseli Ehr. Body colorless; nucleus ribbon-shaped; often attached by a short case; length 1 mm.

Family 4. HALTERIIDAE.

Body spherical or ovoid, often with long bristles and a few cilia scattered over the body; animal moves by springing: 2 genera.

Fig. 104—*Halteria grandinella* (Bronn).

1. Halteria Dujardin. Body small, spherical, with anterior adoral ciliated zone, and usually body bristles: 2 species; in fresh water.

H. grandinella (O. F. Müller) (Fig. 104). Length .04 mm.

2. Strombidium Claparède and Lachmann. Like *Halteria,* but without the bristles: 6 species; in fresh and salt water.

S. caudatum Fromentel. Caudal appendage present; length .035 mm.: in fresh and salt water.

Family 5. TINTINNIDAE.

Body attached by a stalk to a cup: 5 genera.

Fig. 105 — *Tintinnopsis beroidea* (Calkins).

1. Tintinnopsis Stein. Animal in a chitinous cup on which are embedded sand granules; anterior end has two circles of cilia: numerous species; marine.

T. beroidea St. (Fig. 105). Cup thimble-shaped; length .05 mm.: Woods Hole.

T. davidoffi Daday. Cup elongate with a long spine; length .23 mm.

2. Tintinnus Ehrenberg. Like *Tintinnopsis* except that no sand grains are imbedded in the cup: numerous species; in fresh and salt water.

T. amphora Claparède and Lachmann. Length .1 mm.; cup elongate: marine; Cold Spring Harbor.

Order 3. HYPOTRICHIDA.

Body flattened and with cilia, spines, cirri, and membranelles confined to the ventral surface; dorsal surface may have bristles: 3 families.

Key to the families of *Hypotrichida* here described:

a_1 Body usually elongate and broad, with ventral cilia.....1. OXYTRICHIDAE
a_2 Body more or less circular with very long bristles and cilia usually absent. 2. EUPLOTIDAE

FAMILY 1. OXYTRICHIDAE.

Body somewhat elongate with arched dorsal and flat ventral side, the latter with cilia, bristles, etc.; mouth near the middle with an oral groove running backwards: 21 genera; in fresh and salt water.

Key to the genera of *Oxytrichidae* here described:

a_1 Several median longitudinal rows of continuous cilia.
  b_1 Five or more rows of cilia.
    c_1 Mostly fresh-water animals.....1. UROSTYLA
    c_2 Marine animals.....2. EPICLINTES
  b_2 Less than 5 rows of cilia.
    c_1 Neither anterior nor anal bristles; body acute anteriorly..3. STICHOTRICHA
    c_2 Such bristles present; body usually broad.
      d_1 Animals mostly marine.....4. AMPHISIA
      d_2 Animals mostly in fresh water.
        e_1 Two median rows of cilia.
          f_1 Three anterior and no anal bristles.....5. UROLEPTUS
          f_2 No anterior bristles; anal bristles present.....7. HOLOSTICHA
        e_2 Three or 4 rows, body broad and rectangular.....6. ONYCHODROMUS
a_2 No median rows of continuous cilia; but marginal rows present.
  b_1 No caudal bristles.....8. OXYTRICHA
  b_2 Three long caudal bristles.....9. STYLONYCHIA

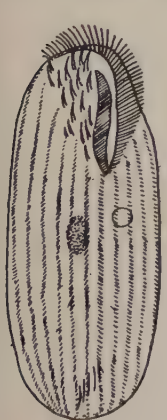

Fig. 106
Urostyla trichota (Conn).

1. UROSTYLA Ehrenberg. Body flexible, elliptical, with longitudinal striations and rows of cilia; oral groove at forward end; 5 to 12 long anal bristles in an oblique row, and 3 or more anterior bristles: 6 species; in fresh and salt water.

U. trichota (Stokes) (Fig. 106). Length .3 mm.; 5 anal and about 20 anterior bristles: in fresh water.

2. EPICLINTES Stein. Body flexible, elongate, the forward half being ovate, the hinder end slender and cylindrical; several longitudinal rows of cilia: 1 species; marine.

E. radiosa Quennerstedt (Fig. 107). Length .045 mm.; 5 large bristles at forward end: Woods Hole.

Fig. 107—*Epiclintes radiosa* (Calkins).

3. STICHOTRICHA Perty. Body cylindrical and very contractile, with acute forward end; oral groove extending back to middle of body; 2 or 3 rows of cilia; color often green: 4 species; in fresh and salt water.

S. secunda Perty (Fig. 108). Length .2 mm.: in fresh water.

4. **Amphisia** Sterki. Body elongate and cylindrical and contractile, with rounded ends and often tinged red or yellow; several anterior bristles and 5 to 10 anal bristles; oral groove extends back to middle of body: 7 species; in fresh and salt water.

Fig. 108

Fig. 109

Fig. 110

Fig. 108—*Stichotricha secunda* (Conn). Fig. 109—*Amphisia kessleri* (Calkins). Fig. 110—*Uroleptus longicaudatus* (Conn).

A. kessleri (Wrzesniowski) (Fig. 109). Body wider anteriorly; length .13 mm.: marine; Woods Hole.

5. **Uroleptus** Ehrenberg. Body cylindrical or flattened and slender with rounded anterior and acute posterior ends; 3 anterior and no anal bristles; oral groove short; 2 continuous rows of median cilia: 5 species; in fresh and salt water.

U. longicaudatus Stokes (Fig. 110). Length .2 mm.: in fresh water.

Fig. 111
Onychodromus grandis (from Bronn).

6. **Onychodromus** Stein. Body broad, somewhat rectangular; 3 or 4 rows of ventral cilia; one row of large cilia along the oral groove: 1 species.

O. grandis St. (Fig. 111). Length .35 mm.; width .12 mm.: in fresh water; slow of movement.

7. **Holosticha** Wrzesniowski. Like *Oxytricha* except that there are 2 rows of median cilia and no anterior bristles.

H. vernalis Stokes. Body elliptical, rounded at both ends; length .07 mm.: in fresh water.

8. **Oxytricha** Ehrenberg. Body elliptical, with a row of cilia along each lateral margin and a mid-ventral group of bristles, consisting of about 8 bristles along the oral groove, about 5 in middle of the body, and about 5 anal bristles: several species; in fresh and salt water.

O. pellionella (O. F. Müller). Body elongate; length .09 mm.: in fresh water.

O. bifaria Stokes (Fig. 112). Body broad; length .2 mm.; bristles in a single line: in fresh water.

9. **Stylonychia** Ehrenberg. Body elliptical, rigid; oral groove triangular or semicircular, reaching middle of body; cilia and bristles as in *Oxytricha;* usually 3 long caudal bristles present: 6 species; in fresh and salt water; very common, the animals often moving by quick jerks.

Fig. 112
Oxytricha bifaria (Conn).

S. pustulata Ehr. Body broad; length .25 mm.; width .1 mm.: in infusions.

S. mytilus (O. F. Müller) (Fig. 113). Body broadest in front of middle; length .3 mm.: in fresh water.

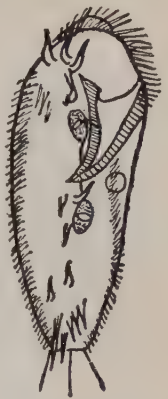

Fig. 113
Stylonychia mytilus (Doflein).

Family 2. EUPLOTIDAE.

Cilia very little developed or absent; large bristles and spines characterize the ventral surface; nucleus ribbon-shaped; body round or oval: 5 genera; mostly marine.

Key to the genera of *Euplotidae* here described:

a_1 No posterior hook-like projection at side of body.
b_1 Anterior bristles present.
c_1 About 9 anterior bristles.....1. Euplotes
c_2 About 6 anterior bristles.....2. Diophrys
b_2 No anterior bristles.....3. Uronychia
a_2 Posterior hook-like projection at side of body.....4. Aspidisca

1. Euplotes Ehrenberg. Body oval or round, either green or colorless; mouth in the hinder half of body, a long arched oral groove joining it with the front end of the body; about 9 large bristles opposite the groove and a similar number of anal bristles: 5 species; in fresh and salt water.

Fig. 114

Fig. 115

Fig. 114—*Euplotes charon* (Calkins). Fig. 115—*Diophrys appendiculatus* (Calkins).

E. charon (O. F. Müller) (Fig. 114). Length .045 mm.: in fresh and salt water.

2. Diophrys Dujardin. Like *Euplotes* except that about 6 anterior and 8 anal bristles, all very long and thick, are present; movement rapid and continuous, not by jumps: 2 species; marine.

D. appendiculatus Stein (Fig. 115). Length .05 mm.: Woods Hole.

3. **Uronychia** Stein. Like *Euplotes* except that no anterior and about 10 great anal bristles are present; movement rapid, with frequent jumps: 2 species; marine.

U. setigera Calkins (Fig. 116). Length .04 mm.: common at Woods Hole.

Fig. 116

Fig. 117

Fig. 116—*Uronychia setigera* (Calkins).
Fig. 117—*Aspidisca hexaris* (Calkins).

4. **Aspidisca** Ehrenberg. Body oval with a short oral groove in the middle of the body and a short posterior projection at the side of body; about 8 thick, anterior, and 6, or more, anal bristles: in fresh and salt water.

A. hexaris Quennerstedt (Fig. 117). Length .07 mm.; 6 anal bristles: Woods Hole.

Order 4. PERITRICHIDA.

Cylindrical or cup-shaped infusorians in which the body is without cilia except those forming the adoral zone at the oral groove, and in a few cases a zone at the hinder end; most of them are sessile: 3 families.

Key to the families of *Peritrichida* here described:

a_1 Body attached by a broad sucking disc.....1. Lichnophoridae
a_2 Body usually attached by a slender stalk.....2. Vorticellidae

Family 1. LICHNOPHORIDAE.

Forward part of the body with an oval oral groove; the hinder part stalk-like and broadened at the end to form a sucking disc provided with a ring of cilia, by which the animal fixes itself: 1 genus; marine; usually parasitic on mollusks.

Lichnophora Claparède. Characters given above.

Fig. 118—*Lichnophora macfarlandi* (Calkins).

L. macfarlandi Stevens (Fig. 118). Length .08 mm.; the animal moves about on its pedal disc: Woods Hole, on the egg capsules of *Crepidula* and on annelids.

Family 2. VORTICELLIDAE.

Body cup-shaped and cylindrical and, with one or two exceptions, attached by a stalk at the hinder end; oral groove circular, around the

edge of the cup; body very contractile; animals frequently colonial: 16 genera.

Key to the genera of *Vorticellidae* here described:

a_1 Animals not sessile and without a stalk; parasites or commensals on *Hydra* and other animals.....1. TRICHODINA
a_2 Animals sessile and stalked and not parasitic, although often attached to other animals.
b_1 Body not enclosed in a cup.
c_1 Stalk long or short and not branched; animals solitary.
d_1 Stalk long and contractile.....2. VORTICELLA
d_2 Stalk short and not contractile.
e_1 Oral disc acts like a cover (operculum) which may close the opening of the cup.....3. PYXIDIUM
e_2 No such cover.....4. RHABDOSTYLA
c_2 Stalk branched; animals colonial.
d_1 Stalk contractile.
e_1 Each individual of the colony can contract independently.
5. CARCHESIUM
e_2 The colony contracts as a whole.....6. ZOOTHAMNIUM
d_2 Stalk not retractile, but rigid.
e_1 No operculum.....7. EPISTYLIS
e_2 Operculum present.....8. OPERCULARIA
b_2 Body enclosed in a transparent cup.....9. COTHURNIA

1. TRICHODINA Ehrenberg. Body short, cylindrical or disc-shaped with a ring of cilia around the circular flat base; oral end also flat: parasites or commensals on *Hydra,* planarians, and other small animals, also on the gills of fishes, attaching itself by the sucker-like base or moving over the surface of the body; sometimes entoparasitic in the urinary bladder or intestine of fish or amphibians; several species.

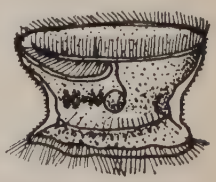

Fig. 119—*Trichodina pediculus* (Conn).

T. pediculus Ehr. (Fig. 119). Length .08 mm.: often common on *Hydra.*

2. VORTICELLA L. Body more or less bell-shaped with the oral groove extending inwards from the rim and with a long stalk; nucleus horse-shoe-shaped; colorless or green or blue: many species; in salt and fresh water, on plants and animals.

V. nebulifera Ehrenberg (Fig. 120). Body campanulate, sometimes green in color, .07 mm. long with a stalk 4 times as long: in clear water.

V. campanula Ehr. The largest *Vorticella,* with a body .2 mm. long or less, bluish in color, and a stalk several times as long, not annulated: in fresh water, often in clumps on water plants.

V. convallaria L. Body annulated, .1 mm. long, with a long stalk: in infusions. This animal is interesting because it was the first microscopic animal discovered by Leeuwenhoek, who first saw it in April, 1675.

V. patellina O. F. Müller (Fig. 121). Body not annulated, with a very wide oral end; length .05 mm.: in fresh and salt water; Woods Hole.

V. marina Greef. Body annulated, .035 mm. long: marine; Woods Hole.

Fig. 120

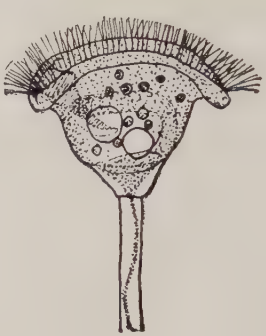

Fig. 121

Fig. 120—*Vorticella nebulifera* (from Bronn).
Fig. 121—*Vorticella patellina* (Calkins).

3. **Pyxidium** Kent. Stalk short and not contractile; body elongate and elliptical, with a small oral end; oral cilia on a disc called the operculum which can close down like a lid.

P. ramosa Stokes. Length .15 mm.: in fresh water.

4. **Rhabdostyla** Kent. Like *Vorticella* but with a short and non-contractile stalk; body bell-shaped or elongate, with small oral end.

R. brevipes (Claparède and Lachmann). Length .1 mm.: in fresh water.

5. **Carchesium** Ehrenberg. Richly branched colonies which form visible grayish masses on water plants and often animals; each individual can contract independently: several species; in fresh water.

C. polypinum (L.) (Fig. 122). Body broad and funnel-shaped and about .1 mm. long: common in fresh and salt water.

Fig. 122
Carchesium polypinum (Dofiein).

6. **Zoothamnium** Ehrenberg. Like *Carchesium,* except that the colony contracts as a whole: several species, in fresh and salt water.

Z. arbuscula Ehr. Body more or less cylindrical; length .05 mm.: on water plants in fresh water.

7. **Epistylis** Ehrenberg. Like *Rhabdostyla,* but colonial; whole colony rigid: numerous species; in fresh and salt water, often on small animals.

E. flavicans Ehr. (Fig. 123). Body bell-shaped, .1 mm. long: in fresh water.

8. Opercularia Ehrenberg. Like *Pyxidium,* but colonial; whole colony rigid: 8 species; in fresh water.

Fig. 123—*Epistylis flavicans* (Conn).

O. articulata Ehr. Body spindle-shaped, truncate at lower end, and .05 mm. long: on water beetles.

9. Cothurnia Ehrenberg. Body elongate and enclosed in a colorless or brownish cup, at the bottom of which it is attached and into which it can retract; cup also attached either directly or by a short stalk: numerous species; in fresh and salt water.

Fig. 124
Cothurnia crystallina (Calkins).

C. crystallina Ehr. (Fig. 124). Length of cup .07 to .2 mm.: in fresh and salt water; Woods Hole.

Subclass 2. SUCTORIA.

Usually sessile *Infusoria* which have no cilia as adults but are provided with long hollow tentacles adapted for sucking or piercing; they attach the tentacles to other *Infusoria* and suck them out; some are entoparasites in *Infusoria:* 8 families with about 200 species.

Key to the families of *Suctoria* here described:

a_1 Body globular, without a cup.....1. Podophryidae
a_2 Body not globular.
b_1 Body usually in a cup at end of a slender stalk.....2. Acinetidae
b_2 Body without cup or stalk; tentacles knobbed.....3. Dendrosomidae

Family 1. PODOPHRYIDAE.

Body globular and not in a cup; stalked or not, and with tentacles of different kinds, some knobbed and some acute: 5 genera.

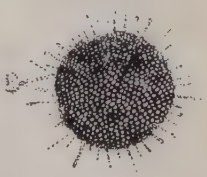

Fig. 125—*Sphærophrya magna* (Conn).

1. Sphærophrya Claparède and Lachmann. Body spherical or ovoid and without stalk, with knobbed tentacles radiating from all sides: free-living in swamps and infusions or entoparasites in *Stentor, Paramecium,* and other ciliates; 4 species.

S. magna Maupas (Fig. 125). Diameter .06 mm.: among water plants.

2. **Podophrya** Ehrenberg. Body spherical or ovoid and attached by a stalk; tentacles knobbed and radiating in all directions, either in groups or not: several species; in fresh and salt water.

Fig. 126

Podophrya gracilis (Calkins).

P. gracilis Calkins (Fig. 126). Diameter of body .008 mm.; stalk very long, measuring .04 mm.: in salt water; Woods Hole.

3. **Ephelota** Wright. Body more or less spherical, with a stalk; tentacles of two kinds, being either pointed and used for piercing, or short and cylindrical and used for sucking: 8 species; marine.

E. coronata Wr. (Fig. 127). Diameter of body .09 to .2 mm.; stalk three times as long, and thickest at the body: common at Woods Hole on campanularians, hydroids, etc.

Family 2. ACINETIDAE.

Body usually in a cup and usually stalked; tentacles knobbed; reproduction by endogenous budding, the spores being ciliated: 4 genera.

1. **Acineta** Ehrenberg. Body in a cup with a stalk: several species; in fresh and salt water.

A. divisa Fraipont (Fig. 128). Body .027 mm. long and does not fill the cup; tentacles long; length of stalk .1 mm.: common on *Bryozoa* at Woods Hole.

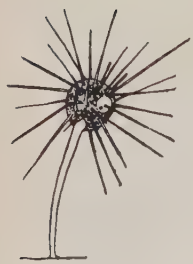

Fig. 127

Fig. 128

Fig. 129

Fig. 127—*Ephelota coronata* (Calkins). Fig. 128—*Acineta divisa* (Calkins). Fig. 129—*Acineta tuberosa* (Calkins).

A. tuberosa Ehr. (Fig. 129). Cup very delicate and often difficult to see; tentacles in usually two groups; color yellow; length of body .33 mm.: at Woods Hole, in salt water.

2. **Tokophrya** Bütschli. Body not in a cup but at the end of a stalk: several species; in fresh and salt water.

T. quadripartita (Claparède and Lachmann). Body .1 mm. long: in fresh water.

Family 3. DENDROSOMIDAE.

Body without cup or stalk; tentacles knobbed and arranged in groups; reproduction as in *Acineta:* 3 genera.

1. **Trichophrya** Claparède and Lachmann. Body irregular in shape and spread out; frequently parasitic: in fresh and salt water.

T. salparum Entz. On the branchial bars of *Molgula:* at Woods Hole; often common.

2. **Dendrosoma** Ehrenberg. Colonial animals on long and branching stalks which spring from a creeping base: 1 species.

Fig. 130—*Dendrosoma radians* (Doflein).

D. radians Ehr. (Fig. 130). Colony up to 2 mm. high: in fresh water.

PHYLUM II.

CŒLENTERATA.

The cœlenterates are radially symmetrical animals which possess but a single internal cavity and no cœlom (Fig. 131). This cavity is a simple space in a more or less cylindrical body in the lowest cœlenterates, but in the larger ones it is often extensively branched. The body wall is composed of three layers, (1) an outer cellular layer, the ectoderm (Fig. 131), (2) an inner cellular layer, the entoderm, and (3) a tissue between them called the middle or supporting layer which is skeletal in function.

This middle tissue in all cœlenterates but the *Ctenophora* is primarily non-cellular, being a secretion of the cellular layers, and is called the mesoglea; in the simplest cases (*Hydrozoa*) (Fig. 131, A) it remains non-cellular, but in the larger and more complex forms (Fig. 131, B) it becomes cellular through the migration of cells into it from the ectoderm or entoderm. In the *Ctenophora* the middle layer is primarily cellular, being a development of the embryonic mesenchyme.

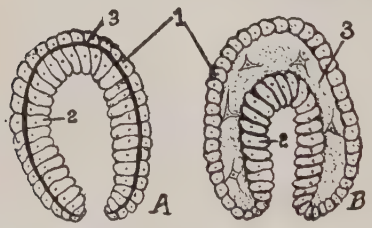

Fig. 131—Diagram of a cœlenterate, with (A) a non-cellular and (B) a cellular mesoglea. 1, ectoderm; 2, entoderm; 3, supporting layer.

The cœlenterates are the lowest many-celled animals and are without most of the organs and tissues which characterize the highest animals. Sexuality is, however, fully developed in all of them, some being hermaphroditic, but the majority being unisexual. Asexual reproduction by fission or budding is also very general and leads to the formation of extensive colonies. Very many exhibit the phenomenon of alternation of generation, in which a sexual, often free-swimming generation alternates with a sessile, usually colonial and asexual generation.

History.—This phylum was constituted in 1847 by R. Leuckart, who separated the polyps, medusae and *Ctenophora* (Eschscholtz) from the *Zoophyta-Radiata* of Cuvier and his contemporaries and called them the *Cœlenterata.* He showed that these animals should be included in

one and the same phylum inasmuch as they are without a cœlom and the hydroid and medusa are usually but stages in the same life history, facts the importance of which had only very recently begun to be understood. Trembley (1744) introduced the term "polypus" because of the fancied resemblance of *Hydra* to the octopus, the polyp of the ancients. The term "medusa" was employed by Linnæus and the older writers because of the resemblance of the tentacles of many jellyfish to the snake-like curls of *Medusa*.

The phylum is composed of 3 subphyla.

Key to these subphyla:

a_1 Sponges; animals sessile, without tentacles.....1. SPONGIARIA
a_2 Hydroids, jellyfish, corals, etc.; no cilia or outer surface; tentacles usually present.....2. CNIDARIA
a_3 Ctenophores; outer surface with 8 ciliated bands; 2 tentacles or none. 3. CTENOPHORA

SUBPHYLUM 1. SPONGIARIA.* (PORIFERA.)

Sessile, aquatic animals, with but few specialized organs and tissues, in which skeletal fibres or spicules usually form an important part of the body. The animals often live in colonies of irregular form in which the various individuals are indistinguishably fused with one another. Numerous pores in the body wall admit water into an interior chamber called the cloacal cavity, of which a large opening called the osculum furnishes an outlet. Sponges are without tentacles and motile appendages of any sort and the adult forms have no locomotory powers.

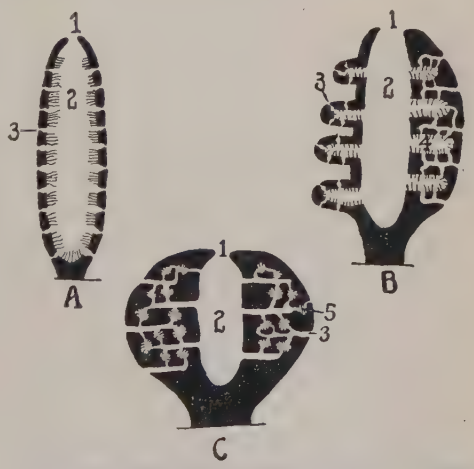

Fig. 132—Diagrams of the 3 types of sponges (Boas). A, ascon type; B, sycon type; C, leucon type. 1, osculum; 2, cloaca; 3, pore canals; 4 radial canal; 5, flagellate chambers.

* See "Rep. of Invertebrate Animals of Vineyard Sound and Adjacent Waters," by A. E. Verrill, Rep. of U. S. Fish. Com., 1871. "Poriferata," by A. Hyatt, Stand. Nat. Hist., Vol. 1, 1888. "Spongiaires," by Delage et Hérouard, Traité de Zool. concrète, 1899. "Sponges," by E. A. Minchen, A Treatise on Zoology, 1900. "Sponges Collected in Porto Rico," by H. V. Wilson, Bull. Fish. Com., Vol. 20, Pt. 2, p. 375, 1900. "Catalogue of Recent Marine Sponges of Canada and Alaska," by W. Lambe. Ottawa Naturalist, Vol. 14, 1900. "Biological Survey of Woods Hole and Vicinity," by F. B. Sumner and others. Bull. Bur. Fish., Vol. 31, 1913.

The simplest sponges (Fig. 132, A) are usually cylindrical structures, either colonial or not, in the walls of which are numerous pores through which water streams into the cloacal cavity; the osculum is at the free end of the body. The body wall is composed of three layers, the outer ectoderm or dermal epithelium (Fig. 133, 1), the middle skeletogenous layer or mesoglea containing the skeletal elements (2), and the entoderm (3) consisting of peculiar cells called collar cells or choanocytes which line the interior cavity. Each collar cell is provided with a single flagellum, the base of which is surrounded by a high ridge or collar.

This simple structure is called the ascon type of sponge. Other sponges have what is called the sycon type of structure (Fig. 132, B). In this the middle layer is much thicker than in the ascon type and from the central cavity numerous cylindrical diverticula called the radial canals (Fig. 132, B, 4) extend into the walls, and communicate also with the outside through pore canals (3). In these sponges the collar cells are confined to the radial canals, the central cavity being lined with a flattened epithelium. Still another type of sponge (Fig. 132, C) is called the leucon or rhagon type, in which the skeletogenous layer is still thicker than in the sycon type and the collar cells are confined to widened portions of the radial canals called the flagellate chambers (5).

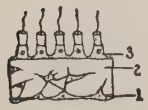

Fig. 133

Body wall of sponge (Lendenfeld). 1, ectoderm (collar walls); 2, supporting layer; 3, entoderm.

The great majority of sponges belong to the leucon type; in these the middle layer constitutes by far the greater part of the body of the animals.

The ectoderm forming the dermal epithelium in all sponges is a single layer of flattened cells which in a few cases (*Oscarella*) is ciliated. In many sponges the ectoderm is more or less glandular and in all it is contractile, the contractile elements in it being elongated cells called myocytes which form sphincters around the pores and oscula and often also surround the cloacal and other cavities; the ectoderm is also sometimes sensitive.

The mesoglea varies much in thickness in different sponges, being generally thin in the smaller and more primitive sponges and thick in the higher and larger ones. It arises as a secretion of the ectoderm and contains various cellular elements, and usually also calcareous or silicious spicules, or horn-like fibres composed of a substance called spongin.

The spicules are of a great variety of forms and fall into two general groups which are called megascleres and microscleres (Fig. 134). The former are usually elongate or radiate in form and are often bound

together by spongin or connective tissue fibres or articulate together to form a network, and constitute the supporting framework of the body. The latter are minute flesh spicules of a variety of forms which are scattered throughout the tissues.

The cellular elements of the mesoglea fall into two distinct groups: (1) those which are derived from the ectoderm, and (2) the archeocytes. The former migrate into it and are either scleroblasts which secrete the spicules, the spongioblasts which secrete the spongin fibres, or the collencytes or connective-tissue cells which are distinguished by their stellate form and thread-like pseudopodial processes. The archeocytes are primitive cells derived from the blastomeres during development, which perform a variety of important functions. They are amœboid cells which are nutritive in function, ingesting and digesting food, and also supply a circulatory element in that they aid in distributing nutriment. They also give rise to the reproductive elements—the spermatozoa, the ova, and the gemmules.

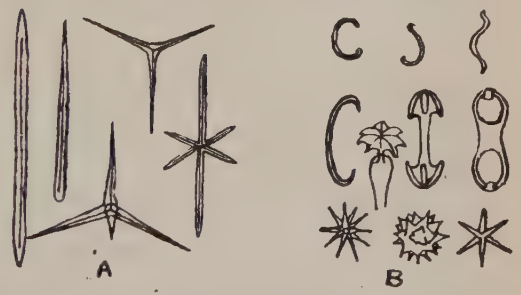

Fig. 134.—Spicules of sponges (Minchin). A, *megascleres*; B, *microscleres*.

The entoderm consists uniformly of collar cells in all sponges. The flagella of these cells do not act in unison, but each for itself, and have for their main function the creation of currents in the water which bring the animal food and oxygen and carry away the wastes. The current thus produced enters the pores, traverses the radial canals and flagellate chambers into the cloacal cavity and passes out again through the osculum. The food consists of organic particles and minute animals and plants; these are ingested and digested by the collar cells in the lower, calcareous sponges, but in the greater majority of them principally by the amœboid archeocytes. No special excretory or respiratory organs and no muscles, nerves or sense organs are present in sponges, although, as we have seen, contractility is present in the ectodermal cells, and sensitiveness to external stimuli is often noticeable.

Sponges have three methods of reproduction: (1) by budding, (2) by the formation of gemmules, and (3) by sexual methods. Budding is simply growth which results in the formation of new oscula, each osculum representing a new individual; it is of very general occurrence. In a few sponges the bud becomes separated from the parent sooner or

later and leads an independent life, but in most of them the buds are indistinguishably joined together so that a colony results, the members of which form a compact whole.

Gemmule formation occurs in all fresh-water and some marine sponges and is a provision against cold weather in temperate regions and in the tropics against desiccation. With the approach of the unfavorable season, archeocytes migrate to one spot in the middle layer, the cells of which secrete a capsule around them. When the sponge dies the gemmule falls to the bottom and remains, in the case of the fresh-water sponge, until the following spring, when the capsule bursts and the archeocytes within move out and develop into a sponge. Many fresh-water sponges live through the winter, however, notwithstanding the formation of gemmules.

Some sponges are hermaphroditic, others are unisexual. No specialized sexual organs are present, the ova and spermatozoa developing from the archeocytes. The ciliated larva swims actively about in the water, but finally attaches itself and after a metamorphosis develops into the adult animal.

Sponges are world-wide in their distribution and, with the exception of the *Spongillidae,* are all found in the sea, where they range from tide lines to very great depths. The fresh-water sponges occur in lakes and streams in all countries.

History.—Aristotle was acquainted with sponges and knew that they were animals, although he notes their likeness to plants. Through the ages following his times, opinions differed concerning them, some people believing them to be plants, others animals, while many ascribed both an animal and a plant nature to them. Ellis (1765) first described the currents of water which stream into and out of sponges. Lamarck classified them with polyps. Robert Grant (1825) definitely proved their animal nature, showing that water flowed into the sponge through numerous minute pores and out through the oscula, and he correctly inferred that ciliary action caused the flow. Many competent naturalists, however, still believed them to be plants, and the question was not finally settled until about 1870 or later. H. J. Clark (1866) first demonstrated the collar cells and laid the foundation for the belief which prevailed for some time that sponges are colonial flagellate *Protozoa.* The embryological investigations of F. E. Schulze and others, however, have tended to overthrow this belief, and sponges are at present usually classified under the *Metazoa* either as a separate phylum or under the *Cœlenterata.*

The *Spongiaria* include about 2,500 living and a large number of fossil species, and are grouped in 3 classes.

Key to the classes of *Spongiaria:*

a_1 Small marine sponges with calcareous spicules and large collar cells and mostly under 2 cm. in length.....1. CALCAREA
a_2 Usually larger sponges with silicious spicules or spongin fibres, or both, or without either.
b_1 Glass sponges; spicules usually six-rayed.....2. HEXACTINELLIDA
b_2 Massive sponges without six-rayed spicules; skeleton of silicious spicules, spongin or both, or wanting.....3. DEMOSPONGIAE

CLASS 1. CALCAREA.*

Marine sponges of small size with 1-rayed, 3-rayed or 4-rayed calcareous spicules; most of them are cylindrical in shape, colorless, either solitary or colonial, and live in shallow water: 2 orders with about 150 species.

Key to the orders of *Calcarea:*

a_1 Body wall thin and porous; central cavity lined with collar cells. 1. HOMOCŒLA
a_2 Body wall not thin; central cavity without collar cells.....2. HETEROCŒLA

ORDER 1. HOMOCŒLA.

Very simple, thin-walled sponges in which the central cavity contains the collar cells; each pore in the body wall is a perforation of a single thickened dermal cell leading into the cavity: 2 families and over 50 species.

FAMILY LEUCOSOLENIIDAE.

With the characters given above; no radial canals or flagellate chambers; with straight, triradiate, or quadriradiate spicules: 4 genera.

1. LEUCOSOLENIA Bowerbank. Usually colonial, although sometimes simple sponges, consisting of a mass of narrow anastomosing tubes: numerous species.

L. botryoides Bow. (Fig. 135). Sponge up to 35 mm. long, ivory white in color, and consisting of a mass of slender tubes; spicules 1 and 3-rayed and faint yellow in color: in shallow water; Martha's Vineyard to Gulf of St. Lawrence; Europe.

Fig. 135—*Leucosolenia botryoides* (Hegner).

L. cancellata Verrill. Sponge massive, consisting of small anastomosing tubes, up to 3 cm. in length and yellowish in color: walls thin, with triradiate and quadriradiate spicules: Casco Bay to Arctic Ocean.

* See "Die Kalkschwämme," by E. Haeckel, 1872.

L. fragilis* Haeckel (*Ascortis fragilis* Haeck.). Color white or yellowish; spicules both straight or somewhat arched and triradiate; separate individuals 1 to 1.5 mm. long; colony 5 to 10 mm. in diameter: in shallow water from Long Island Sound to Gulf of St. Lawrence; common; Europe.

Order 2. HETEROCŒLA.

Small sponges usually more or less cylindrical in form with thick walls and a cloacal cavity lined with a flat epithelium and not with collar cells, the latter being confined to more or less well-defined chambers or in radial tubes which are joined by means of small inhalent dermal canals with the outside; either solitary or colonial: 6 families and about 90 species.

Family 1. GRANTIIDAE.

Radial tubes extending outwards from the cloacal chamber; distinct and continuous layer (dermal cortex) peripheral to the radial canals; no conspicuous quadriradial spicules lining cloacal cavity: about 13 genera and 40 species.

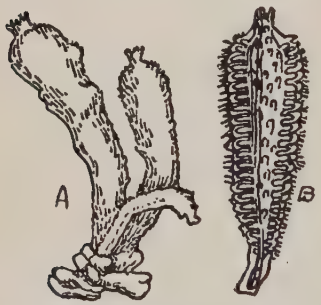

Fig. 136—*Grantia ciliata* (Kellogg). A, group of 3 individuals; B, longitudinal section.

1. Grantia Fleming. Triradial spicules filling mesoglea and projecting into cloacal cavity; cortex thin: 20 species.

G. ciliata (Fabricius) (Fig. 136). Solitary sponges, 12 mm. high and 3 mm. thick; 2 kinds of monaxial spicules, a longer kind protecting the osculum and a shorter in the cortex protecting the inhalent canals: Rhode Island to Greenland, from low water line to 60 fathoms; Europe; often common.

G. canadensis Lambe. Body 3 mm. high and 1 mm. thick: Gulf of St. Lawrence and northerly.

Family 2. LEUCONIDAE.

Collar cells in spherical flagellate chambers from which branched, exhalent canals extend to the cloacal cavity: 5 genera.

Leucandra Haeckel. Spicules without regular arrangement: many species.

* See "On the Spongiae Ciliatae," etc., by H. J. Clark, Mem. Bost. Soc. Nat. Hist., Vol. 1, p. 305, 1866.

L. taylori Lambe. Sponge small, solitary, globose, 6 mm. high and 4.5 mm. thick, with thick walls and a narrow cloacal cavity; spicules triradiate, with long monaxials protecting the osculum: Vancouver Island.

Family 3. AMPHORISCIDAE.

Conspicuous subdermal quadriradiate spicules with elongated inwardly directed rays: 5 genera.

Amphoriscus Haeckel. Cortex thin; spicules triradial and quadriradial: several species.

A. thompsoni Lambe. Gulf of St. Lawrence.

Class 2. **HEXACTINELLIDA.*** (Triaxonia.)

Glass sponges. Sponges with usually rather thin walls and a large cloacal cavity giving them a more or less tubular or basket-like shape; spicules silicious, consisting of 3 crossed axes making them either 6-rayed or belonging to the 6-rayed type, and either solitary or joined to form a continuous skeleton which often has the appearance of spun glass; cloacal cavity large and unusually more or less cylindrical, usually with simple radial flagellate chambers opening out from it, the wall of the cloacal cavity, however, often folded and the chambers branched: about 12 families.

Fig. 137—*Euplectella* (from Weysse).

Family 1. EUPLECTELLIDAE.

Body elongate, usually curved or twisted; spicules joined together forming a network; upper end the larger with a terminal sieve-like plate; lower end with usually a mass of long silicious threads which fastens the animals in the mud: several genera.

Euplectella Owen (Fig. 137). With the characters of the family: several species.

E. suberea Wyville Thomson. Body a straight, cylindrical, slightly swollen tube, 25 cm. long and 5 cm. in diameter: West Indies, in deep water.

Family 2. HYALONEMATIDAE.

Body globose, elongate or cup-shaped with a long stalk composed of long twisted silicious strands; several genera.

Hyalonema Gray. Body funnel or cup-shaped: several species.

* See "Report on the Hexactinellida," by F. E. Schulze, Chall. Rep., Vol. 21, 1887.

H. longissimum Verrill. Length 40 cm.: in 60 to 95 fathoms off the New England coast.

Class 3. DEMOSPONGIAE.

Usually massive and often brightly colored sponges with thick walls and small round flagellate chambers connected by branched exhalent canals with the cloacal cavity; spicules very varied in form, being often monaxonic and straight and needle-like, or tetraxonic with 4 crossed axes, giving them 8 rays; spongin either present with the spicules or not, or the fibres alone may be present or both be wanting: 4 orders.

Key to the orders of *Demospongiae:*

a_1 Skeleton formed of tetraxonic silicious spicules of a variety of forms without needle-like spicules and without spongin; in rare cases no skeleton. 1. Tetractinellida

a_2 Skeleton of needle-like spicules with often others and with or without spongin fibres ..... 2. Monactinellida

a_3 Skeleton of spongin fibres alone ..... 3. Ceraospongiae

a_4 Skeleton entirely wanting ..... 4. Myxospongiae

Order 1. TETRACTINELLIDA.*

Sponges with usually a hard outside crust or cortex containing megascleres which form the principal framework of the body, microscleres occurring throughout the mesoglea and being of a variety of forms, but usually reducible to the tetraxonic type: 8 families and over 325 species.

Family 1. THENEIDAE.

Body usually more or less mushroom-shaped with the osculum in the center: 1 genus.

Thenea Gray. With the characters of the family: several species.

T. echinata Verrill. Body 5 to 10 cm. broad and not quite so high, with a short, thick stalk; upper portion with radiating bundles of spicules which project beyond the surface: New England coast north of Cape Cod.

Family 2. GEODIIDAE.

Body globose with a thick crust, provided with masses of spherical spicules: about 8 genera and 180 species.

Geodia Lamarck. Tetraxonic needles radially arranged and confined to the periphery; oscula sieve-like, in groups; incurrent openings also sieve-like and scattered: 70 species.

G. mülleri (Fleming). Spherical or flattened in youth, later irregularly lobed; diameter and thickness sometimes 30 cm.: cosmopolitan; Jamaica; West Indies.

* See "Tetraxonia," by R. von Lendenfeld, Das Tierreich, 1903.

Order 2. MONACTINELLIDA.

Sponges in which the skeleton consists of needle-like (monaxonic) spicules and sometimes other kinds, with or without spongin fibres: 20 families, grouped in 2 suborders, and numerous species, constituting the majority of all sponges; mostly in shallow water; 1 family in fresh water.

Key to the suborders of *Monactinellida:*

a_1 Sponge compact, usually massive.....1. Hadromerina
a_2 Sponge not compact, usually with spongin.....2. Halichondrina

Suborder 1. HADROMERINA.

Body compact, having a hard outside crust or cortex, and usually massive but sometimes cup-shaped or stalked; spongin absent or very poorly developed: 8 families.

Family 1. TETHYIDAE.

Body spherical, with slight projections on the surface caused by the protrusion of the end of bundles of long needles (megascleres) without heads which extend radially from the centre of the body; no spongin fibres present: 6 genera.

Tethya Lamarck. Body with a thick, leathery rind and the form and color of a small orange: several species.

T. hispida Bowerbank. In 8 to 35 fathoms in Casco Bay, Maine.

Family 2. SUBERITIDAE.

Form massive; substance compact and firm; spicules (megascleres) are needles with heads; without microscleres or spongin: 15 genera.

Suberites Nardo. Form various, often massive, sometimes pedunculate; outer surface smooth: 15 species.

S. compacta Verrill. Body irregular, being an elongated mass attached by one edge; length up to 15 cm.; width and height 2 to 8 cm.; color bright yellow; surface smooth; oscula inconspicuous: Maine to Virginia in shallow water; often on the shells of hermit crabs.

Family 3. POLYMASTIIDAE.

Form massive, often spherical, with long needles extending radially from the centre; with the surface covered with small protuberances, some of which have an osculum; no microscleres or spongin: 13 genera.

Polymastia Bowerbank. Smaller needle and pin-shaped spicules in addition to the radial ones present.

P. robusta Bow. Form irregular; color yellow or gray; diameter

up to 30 cm.; with finger-like branches 4 to 10 mm. long: North Carolina to Maine and northerly in 1 to 8 fathoms; very common in Long Island Sound; Europe.

Family 4. CLIONIDAE.

Sponges which bore in shells or limestone by some process not understood; monaxial spicules of various forms: 4 genera.

Cliona Grant. The sponge begins its existence by boring in the dead or living shells of various mollusks; it honeycombs the shell, and after having destroyed it, grows over it, forming a mass often 15 or 20 cm. in diameter, on the surface of which are small elevations.

C. celata Grant. Sulphur sponge. Color bright yellow: very common from South Carolina to Maine in 1 to 12 fathoms; cosmopolitan.

Suborder 2. HALICHONDRINA.

Body not compact but usually fibrous, without a cortex; spongin usually well developed: 13 families.

Family 1. SPONGILLIDAE.*

Fresh-water sponges. Body variable in shape and forming an irregular mass incrusted on stones, sticks, plants, etc., up to the size of the hand, or larger, and yellow or brown in color, or green where exposed to the sunlight, as the result of the presence of *zoochlorellae;* spicules of two principal kinds, (1) the megascleres, slightly curved needles or rods occurring in the mass of the sponge and (2) the microscleres, much smaller needles, rods or amphidiscs (two star-like plates joined by a rod) (Fig. 139, B) which occur in the sponge or form the shell of the gemmules; asexual reproduction by gemmules, these being globose buds about .5 mm. in diameter, which may occur throughout the sponge, being present mostly in the latter part of the summer and in the fall: about 10 genera and 50 species, of which 21 occur in this country; in fresh and sometimes brackish water, both in running streams and in ponds and lakes, from the surface to a depth of 200 feet; cosmopolitan.

Key to the American genera of *Spongillidae:*

a_1 Gemmules without tendrils or projections.
  b_1 No amphidiscs present.....1. Spongilla
  b_2 Amphidiscs present.
    c_1 Discs of amphidiscs of same size.
      d_1 But one type of amphidiscs.....2. Ephydatia
      d_2 Two types of amphidiscs.....3. Heteromeyenia
    c_2 Discs of unequal size.....4. Tubella
a_2 Gemmules with tendrils or projections.....5. Carterius

* See "A Monograph of the Fresh Water Sponges," by E. Potts, Proc. Acad. Nat. Sci., Phila., for 1887. "Spongillidae," by W. Weltner. Süssw. F. Deutschl., Heft 19, 1909.

1. Spongilla Lamarck. Gemmule without amphidiscs, but surrounded by needles or rods alone; large needles usually smooth: 17 species, 6 American.

S. lacustris (L.) (Fig. 138). Sponge branching and usually green, with smooth longer (megascleres) and rough shorter (microscleres) needles; gemmules surrounded by spiny curved rods, but occasionally without them, and often scarce until late in the fall: cosmopolitan, preferring running water and sunlight; the commonest fresh-water sponge.

Fig. 138—A, spicules of *Spongilla lacustris;* B, gemmule of same (Süssw. F. Deut.).

S. fragilis Leidy. Sponge not branching, growing in flat patches, usually yellow or brown but occasionally green in color; gemmules abundant, in one or more layers at the base of the sponge; large needles smooth; no microscleres in body of sponge: in standing and running water and avoiding the light; next to the above, the commonest species.

2. Ephydatia Lamouroux (*Meyenia* Carter). Gemmule with amphidiscs all of one type: 17 species, 8 American.

E. fluviatilis (L.) (Fig. 139). Sponge massive, occasionally lobate; color yellow or brown, sometimes green; needles smooth or rough with only the tip smooth; no smaller needles present: cosmopolitan; in standing and running water, preferring the former.

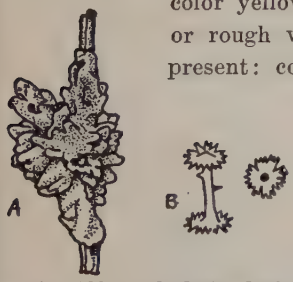

Fig. 139—*Ephydatia fluviatilis.* A, entire sponge attached to a stick; B, amphidiscs in gemmule (Süssw. F. Deut.).

3. Heteromeyenia Potts. Similar to *Ephydatia,* but the gemmule has amphidiscs of two different types, the less numerous being much longer than the other and with long hooked rays on the discs: 3 species, all American.

H. ryderi Potts. Sponge massive, often hemispherical, lobed, light green in color; needles rough, except at the tips; long amphidiscs with spiny shaft and discs consisting of 3 to 6 recurved hooks; short amphidiscs with usually smooth shaft and large flat discs: eastern and central North America, in shallow-flowing water.

4. Tubella Carter. Discs of amphidisc of very unequal size, giving it the shape of a collar button; needles rough, sometimes with rounded tips: 5 species, 1 American.

T. pennsylvanica Potts. Sponge minute, being 6 mm. in diameter, incrusting, gray or green in color; gemmules very numerous: eastern North America, in shallow water.

Fig. 140
Portion of gemmule of *Carterius tenosperma* (Süssw. F. Deut.).

5. **Carterius** Potts. Aperture of gemmule with a chitinous lining which is prolonged into a tube which is expanded at its outer margin and often divided into long tendrils: 5 species, 3 American.

C. tenosperma Potts (Fig. 140). Sponge yellowish-green; needles rough, both long and short being present; gemmules with 3 to 5 twisted tendrils which may be 12 mm. long; amphidiscs as in *Ephydatia:* eastern United States; on water plants or shells.

Family 2. CHALINIDAE.

Form various; usually branched; spongin fibres often well developed; spicules needle-shaped; some species form gemmules like fresh-water sponges: about 40 genera, all marine.

Key to the genera of *Chalinidae* here described:

a_1 Spongin fibres form a regular network.....1. Chalina
a_2 Spongin fibres little developed.
b_1 Spicules connected at their tips to form a network.....2. Reniera
b_2 Spicules confusedly massed together.....3. Halicondria

1. Chalina Bowerbank. Sponges in which the spongin forms a regular rectangular network in which the spicules are imbedded: several species.

C. oculata (Pallas) (Fig. 141). Finger sponge. Thick, more or less flattened, forked or digitate stalks with round orifices 2 mm. in diameter scattered over them; color orange or red: very common from Rhode Island to Labrador, in 1 to 80 fathoms.

Fig. 141—*Chalina oculata* (Shaffer).

C. arbuscula Verrill. Dead men's fingers. Body a cluster of branches, 10 to 20 cm. long and 5 to 10 mm. in diameter, of delicate texture and white or gray in color: North Carolina to Cape Cod in 1 to 8 fathoms; very common in Long Island Sound.

2. Reniera Schmidt. Form various, very fragile, easily pulverized; spongin very little developed; spicules straight needles joined at their tips, and arranged to form a network: numerous species.

R. mollis Lambe. Body massive, lobate, 9 cm. long, 5 cm. high and 3 cm. thick; oscula large, 5 mm. in diameter; surface rough; color yellowish: Labrador; Vancouver.

3. Halicondria Fleming. Massive sponges of various shapes with needle-like spicules confusedly massed together, and with but little spongin: numerous species.

H. panicea (Pallas). Color gray, yellowish or orange: from Rhode Island to the Arctic Ocean, in 4 to 8 fathoms; Europe.

Family 3. ESPERELLIDAE.

Form various, a distinct network of spongin being present with needles of various forms, one of which is C-shaped: numerous genera.

Fig. 142

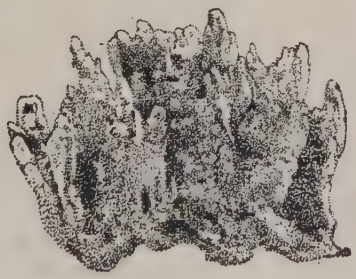

Fig. 143

Fig. 142—*Microciona prolifera* (Wilson). Fig. 143—*Stylotella heliophila* (Parker).

1. Esperella* Vosmaer. Amorphous sponges with needle-like spicules predominating; spongin usually distinct: several species.

E. fibrexilis H. V. Wilson. Irregular sponges, yellowish-brown in color, about 10 cm. in diameter, covered with algae, hydroids, etc., with a dermal membrane, beneath which are subdermal cavities; spicules few; gemmules formed during the summer: Woods Hole, on docks.

2. Microciona Bowerbank. Sponge incrusting and irregular in form, with straight or bent needle-like spicules and stout spongin fibres: cosmopolitan.

* See "Observations on the Gemmule and Egg Development of Marine Sponges," by H. V. Wilson, Jour. Morph., Vol. 9, p. 277, 1894.

M. prolifera (Ellis and Solander) (Fig. 142). Bright-red sponges incrusting on stones, shells, etc., when young, rising in digitate masses sometimes 15 cm. high: South Carolina to Cape Cod from low water mark to 10 fathoms; very common in Long Island Sound.

3. **Stylotella*** Lendenfeld. Erect, incrusting sponges with very little spongin and with needles in bundles; no microscleres; texture soft, no hard rind present.

S. heliophila H. V. Wilson (Fig. 143). Yellowish sponges, either massive or with erect finger-like processes, 5 to 10 cm. long and 5 cm. high: common on stones and shells in shallow water, North Carolina.

Order 3. CERAOSPONGIAE.

Sponges in which the skeleton consists of a close network of spongin fibres without proper spicules: 4 families and about 40 genera, which are found in tropical and subtropical seas.

Family 1. SPONGIIDAE.

Commercial sponges.† Spongin fibres solid, with a slender axial core and frequently enclosing foreign bodies, such as sand; flagellate chambers small with special openings by canaliculi into exhalent cavities: 7 genera and about 20 species, the fibrous skeleton of many of which is used for commercial purposes.

1. **Euspongia** Bronn. Body massive with slender spongin fibres and very small meshes; simple main fibres usually containing sand, the finer connecting fibres without sand: about 12 species; cosmopolitan.

E. officinalis (L.). Levant sponges. Fibres very elastic; form usually more or less globose, often lobed, cup-shaped or lamelliform; color in life dark brown, being lighter beneath and on the sides: eastern Mediterranean; Bahamas; West Indies; Australia; in 1 to 100 fathoms; several varieties are known, of which the most valuable is the light yellow cup-shaped *E. mollissima* from Asia Minor. The American variety, the so-called glove sponge, is one of the least valuable commercial sponges.

2. **Hippospongia** Schulze. Horse sponges. Body massive and permeated by large, often cavernous canals; fibres delicate and forming an irregular network: about 20 species.

* See "The Reactions of Sponges," etc., by G. H. Parker, Jour. Exper. Zool., Vol. 8, p. 1, 1910.

† See "Revision of North American Poriferae, Pt. I and II," by A. Hyatt, Mem. Bost. Soc. Nat. Hist., Vol. 2, 1875 and 1877. "The Sponge Fishery and Trade," by R. Rathbun, U. S. Com. of Fish., Sect. 5, Vol. 2, p. 817, 1887. "The Commercial Sponges of Florida," by H. M. Smith, Bull. U. S. Fish. Com., Vol. 17, p. 225, 1897. "The Commercial Sponges and Sponge Fisheries," by H. F. Moore, Bull. Bur. Fish., Vol. 28, p. 403, 1910.

H. gossypina Hyatt. Sheepswool sponge (Fig. 144). Form variable; surface with numerous projections, between which are the large oscula: Florida and the Bahamas; the most valuable American sponge.

H. equina Schmidt. Horse sponge; yellow sponge; grass sponge; velvet sponge. Body massive, of coarse fibre and with extensive canal system: Mediterranean; West Indies; Florida; much less valuable than the above.

3. **Cacospongia** Schmidt. Fibres rather coarse and brittle; main fibres distinct from the connecting fibres; meshes large: several species.

C. spongeliformis H. V. Wilson. Body cylindrical, somewhat branching, 25 cm. long, 7 mm. thick; texture solid, with subdermal cavities; surface covered with minute conical elevations; dermal membrane with numerous shells, sand, etc., imbedded in it: West Indies.

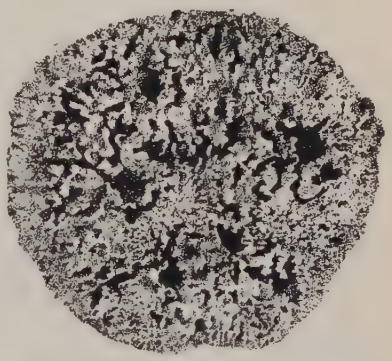

Fig. 144—*Hippospongia gossypina* (Moore).

4. **Hircinia** Nardo. Form variable, sometimes very large; characteristic filaments present found in no other sponges, which are 3 or 4 mm. long, very fine and swollen at the ends: numerous species.

H. acuta Hyatt. Body 10 cm. high, massive, with several oscula; surface with small protuberances; filaments in many places in bundles; color gray, in life blackish: West Indies.

Family 2. APLYSINIDAE.

Fibres hollow, without foreign inclusions; flagellate chambers small; form various: 4 genera.

Aplysina Nardo. Form various but usually digitate; fibres form a close network; surface with protuberances: numerous species.

A. flagelliformis Carter. Body 10 cm. long, cylindrical, branching, 7 mm. in diameter, dark red in color: West Indies.

Order 4. MYXOSPONGIAE.

Sponges without skeleton of any kind: 2 families.

Family HALISARCIDAE.

Slime sponges. Body incrusting and soft, with elongate, sac-like flagellate chambers: 3 genera.

Halisarca Dujardin. Body small, soft and irregular, with large oscula somewhat elevated: several species.

H. dujardini Johnston. Small, pale-yellow, gelatinous sponges growing on red algae: in 5 fathoms, off Rhode Island.

Subphylum 2. CNIDARIA.*

Jellyfish, hydroids, corals, etc. Aquatic animals, either sessile or free-swimming, in which the body possesses a single internal cavity, the gastrovascular space (Fig. 131). This has usually a single opening to the outside, which is called the mouth, and is the common digestive and circulatory cavity; in the simplest cases it is cylindrical in shape, but in the higher and larger forms is much branched, forming a system of canals.

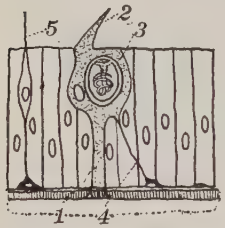

Fig. 145—Diagram of a nettle organ in the ectoderm of a cnidarian (Lendenfeld). 1, cnidoblast; 2, cnidocil; 3, nematocyst; 4, nerve fibre; 5, tactile cell.

The cnidarians are predacious animals and usually possess long vibratile tentacles by means of which they take their prey. These tentacles, as well as other parts of the body, are provided with numerous characteristic organs of peculiar structure called the nettle organs or nematocysts which render them effective instruments in the performance of this important function. A nettle organ (Fig. 145, 3) consists of a spiral, thread-like tube with several barbs at the base which lies coiled within a cavity in a specialized cell called a cnidoblast (1). The cavity is filled with a poisonous fluid; its walls form an ovoid sac, the outer end of which is continuous with the thread-like tube. A minute spine, the cnidocil (2), projects from the free surface of the cnidoblast into the water and when the surface of the ectoderm is irritated, either by actual contact or in other ways, the tube is shot out with

* See "Contributions to the Natural History of the U. S.," Vol. 3 and 4, by L. Agassiz, 1862. "Invertebrate Animals of Vineyard Sound," by A. E. Verrill, Rep. U. S. Fish. Com., 1871. "Les Cœlentères," by Delage et Hérouard, Traité de Zoologie concrète, Vol. 2, 1901. "Hydroids of the Woods Hole Region," by C. C. Nutting, Bull. U. S. Fish. Com., Vol. 19, 1899. "Synopsis of North American Invertebrates, The Hydromedusae," by C. W. Hargitt, Part I, II, III, IV, Am. Nat., Vol. 35, pp. 301, 379 and 575, 1901, and Vol. 37, p. 331, 1903. "The Hydroids of the Pacific Coast of North America," by H. B. Torrey, Univ. of Cal. Pub., Vol. 1, p. 1, 1902. "The Medusae of the Woods Hole Region," by C. W. Hargitt, Bull. Bur. Fish., Vol. 24, p. 21, 1904. "Notes on Cœlenterates of Woods Hole," by C. W. Hargitt, Biol. Bull., Vol. 14, p. 95. "A Synopsis of the Fixed Hydroids of New England," by J. S. Kingsley, Tufts College Studies, Vol. 3, p. 13, 1910. "Medusae of the World," by A. G. Mayer, 1910. "The Hydroids of the West Coast of North America," by C. M. Fraser, Bull. from the Lab. of Nat. Hist. of Univ. of Iowa, Vol. 6, 1911. "Some Hydroids of Beaufort, North Carolina," by C. M. Fraser, Bull. Bur. Fish., Vol. 30, p. 337, 1912. "A Biological Survey of the Waters of Woods Hole and Vicinity," by F. B. Sumner and others, Bull. Bur. Fish., Vol. 31, 1913.

sufficient force to puncture the skin of small animals (Fig. 146), and the poisonous fluid which is thus injected into the wound may cause paralysis or death. The thread tubes also often lasso small animals by winding around hairs and other projections of their bodies (Fig. 146, B). The nettle organs of the larger jellyfish often inflict a painful wound to man.

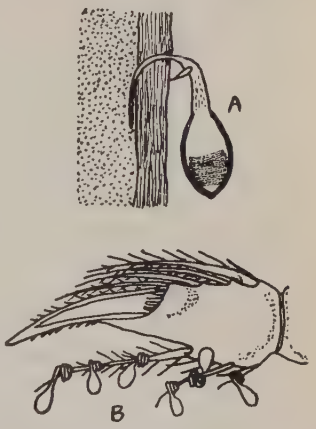

Fig. 146—The action of nettle organs (Toppe). A, a nettle organ piercing the chitinous shell of an insect; B, nettle organs holding a small crustacean by its spines.

The body of the *Cnidaria* is distinctly radiate in structure; in the smallest jellyfish and hydroid polyps the number of radii is usually four and in the larger ones and the *Alcyonaria,* some multiple of four; in the *Zoantharia* it is usually six or a multiple of six.

Two distinctly different types of structures are present among the *Cnidaria,* which are, however, capable of being referred to a common fundamental form. These are: (1) the hydroid or polyp type (Fig. 147, A), and (2) the medusa or jellyfish type (Fig. 147, B, or Fig. 154). The first is seen in the simplest form in the fresh-water *Hydra* and the hydropolyps, and in a more complex form in the corals; in these animals the body is cylindrical in form, one end is usually attached to some more or less stationary object, while at the other end is the mouth surrounded by tentacles.

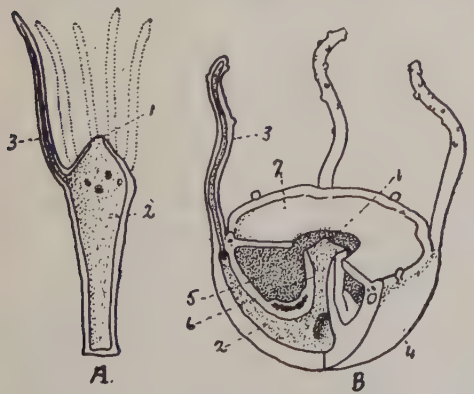

Fig. 147—The two types of structure of cnidarians. A, the hydroid type; B, the medusa type, a quarter of the animal being removed to show the internal structure. (Delage et Hérouard.) 1, mouth; 2, gastrovascular space; 3, tentacle; 4, exumbrella; 5, subumbrella; 6, manubrium; 7, velum.

Two variations of this type are found. In the *Scyphozoa* and the *Anthozoa* (Fig. 219) longitudinal mesenterial ridges project prominently into the gastrovascular space and a gullet lined with ectoderm is present, while in the simpler *Hydrozoa* or *Hydromedusae* these features are wanting (Fig. 147, A). Cnidarians of the hydroid type live in colonies in the majority of cases which often con-

tain thousands of individuals, and grow from one another by process of budding.

The medusa type is seen in its simplest form in the usually minute hydromedusans and in a more complex form in the larger scyphomedusans. In all these animals the body is more or less bell or disc-shaped, the convex side, which is called the exumbrella, corresponding to the attached end of the hydroid polyp, while from the center of the concave side, which is called the subumbrella, extends the manubrium, a more or less cylindrical but often branched projection, at the end of which is the mouth. Tentacles may be present on the manubrium, at the edge of the bell, on the subumbrella or the exumbrella, and may be long or short and flexible or rigid.

Two distinct types of medusae are met with. Those of one type are called craspedote medusae (Fig. 147, B), because they possess a velum (7). This organ is a ridge or membrane containing epithelial muscle fibres, which extends inwards toward the manubrium from the entire edge of the subumbrella. These medusae are almost all small, being usually less than 2 cm. in diameter, although some are larger, *Æquorea tenuis* attaining a diameter of 10 cm. and *Æquorea forskalea* of the Mediterranean one of 40 cm. and, excepting the *Narcomedusae,* have a plain, unscalloped edge. Those of the other type are called acraspedote medusae (Fig. 216); these lack the velum or have it in a rudimentary form and possess a scalloped outer edge, as well as other special features; they are also usually large, some having a diameter of a meter or more. A certain number, however, are small, with a diameter of less than a centimeter.

In *Hydra* and the *Anthozoa* the hydroid or polyp type of structure alone prevails, and the animals produce, either by budding or by sexual methods, young individuals which develop directly into adults similar to the parents. In most *Trachomedusae* and *Narcomedusae,* so far as known, the medusa type alone prevails, the young developing directly into free-swimming medusae. In the *Hydromedusae* and *Scyphomedusae,* on the other hand, both types may prevail in the same species, and the phenomenon of the alternation of generations is exhibited, an asexual generation, which is the hydroid, producing by budding a sexual generation, which in these animals is the medusoid generation. The medusoids are either male or female and produce embryos called planulae, which after a period of free life attach themselves to some fixed object and become hydroid polyps, the medusoid buds, in certain cases, remaining attached to the parent hydroid, and in others becoming free-swimming jellyfish.

In all the *Cnidaria,* the body wall consists of the outer ectoderm, the inner entoderm and the middle mesoglea (Fig. 131). The ectoderm consists of a single layer of cells, among the inner ends of which are small inter-

stitial cells and often epithelial muscle fibres and nerve cells. The mesoglea is skeletal in function and a secretion of the two cellular layers; in the *Hydromedusae* it remains non-cellular and usually thin, but in the other *Cnidaria,* cells migrate into it from the ectoderm and it often becomes very thick, forming the jelly (Fig. 131, 3). The gastrovascular space (Fig. 147) is cylindrical in the hydroid; in the medusa it is a branched cavity which forms a system of canals. Food is taken into the mouth; in the gastrovascular space it is digested and the products of digestion are caused to circulate throughout the body of the colony by the action of the entodermal flagella or cilia. The sexes are separate in *Cnidaria,* with some exceptions, but usually not dimorphic. The sex cells arise in the ectoderm in the lower and in the entoderm in the higher forms. Locomotion is accomplished by means of the muscle fibres which are the inner projections of ectoderm or entoderm cells. The sessile hydroids and *Anthozoa* move their tentacles about actively and can retract and extend the body; the medusae swim slowly through the water by means of the muscle fibres in the velum or in the subumbrella. The nervous system consists of a plexus of nerve cells and fibres among the muscle fibres, some of which, in the medusae, form a double ring in the outer rim of the umbrella and in the acraspedote medusae a rudimentary ganglion at the base of each sense organ. The muscles may also be stimulated directly and without the intermediary of nerve cells or fibres. Special sense organs are absent in hydroids and the *Anthozoa:* in medusae they are present in the margin of the umbrella and may be either visual (ocellate) in function or equilibrial (vesiculate).

History.—Aristotle was acquainted with many cnidarians, especially with actinians and medusae which he named *Acalephae* and *Cnidae,* the latter term referring to the stinging power of the animals. During the succeeding ages and down to about the middle of the eighteenth century the animals were observed and figured by a number of naturalists, but little or no exact knowledge of them existed. They were called either plants or plant-animals (zoophytes) and were often considered the connecting link between the plant and animal kingdoms, a belief that has not entirely disappeared in some localities even down to the present day. Polyp stocks and corals were generally held to be plants, the individual animals being called the flowers. When, however, Trembley in 1744 demonstrated the animal nature of *Hydra* and Peyssonnel in 1753 that of corals, a new era began in the study of cnidarians, and in the following years a large number of them were accurately figured and described by Ellis, Pallas, O. F. Müller, and others. The relation of the polyp to the medusa was, however, still for a long time to be entirely unknown. Cuvier in 1799 was one of the first to study the anatomy of the medusa

and in 1812 brought polyps and medusae together in the single type-group of *Animalia-Radiata.*

The next few years saw an immense increase in the knowledge of both the anatomy of the medusa and the polyp and in the number of the forms known, yet it was not until 1841 that M. Sars, on the basis of his studies of *Aurelia aurita,* and 1842 that Steenstrup, on that of his studies of *Coryne,* could first definitely formulate the principle of the alternation of generations in cnidarians and elucidate the relation of the polyp to the medusa. Even as late as 1837 Lovén held the polyp and medusa to be dimorphic sexual forms, the former being the male and the latter the female individual. In 1847 Leuckart created the phylum *Cœlenterata* and called attention to the fundamental sack form of the body, and in 1849 Huxley showed that the walls of this sack were made up of two layers which he named ectoderm and entoderm and homologized with the two primitive germ layers of the higher animals. In 1851 Vogt introduced the useful term *Hydromedusa,* Huxley in 1856 that of *Hydrozoa,* and Claus in 1891 that of *Scyphozoa.* The latest development of the system is due to many authors, of whom perhaps Chun and A. G. Mayer are especially to be mentioned. The first important American work on cnidarians was J. D. Dana's Report of the *Zoophyta* of the Wilkes Expedition (1846). Louis and Alexander Agassiz and their pupils and followers have done the most to extend the knowledge of American cnidarians. Mayer's monograph, *The Medusae of the World,* is the most important recent work. The subphylum contains about 4,200 species, grouped in 3 classes.

Key to the classes of *Cnidaria:*

a_1 Small hydroid polyps and both small and large medusae.
b_1 Hydroids without mesentarial ridges and usually colonial, and craspedote medusae.....1. Hydrozoa (*Hydromedusae*)
b_2 Minute hydroids with 4 mesentarial ridges, and acraspedote medusae.
2. Scyphozoa (*Scyphomedusae*)
a_2 Corals, sea-anemones and gorgonians.....3. Anthozoa

Class 1. **HYDROZOA.** (Hydromedusae.)

Hydroid polyps and craspedote medusae, usually with alternation of generations. The hydroid stage, which is called the trophosome, is sessile and usually colonial and produces by budding the medusoid stage, which is called the gonosome. The latter is sexual and either male or female. The individual hydroids are small, being usually but a few millimeters in length, the solitary tubularians being exceptions, which may be several centimeters, and in the case of the deep-sea *Branchiocerianthus imperator,* which is allied to *Corymorpha,* a meter or more in length. The colonies are often plant-like in appearance; the individual polyps are called the

hydranths (Fig. 152), the stalks on which they grow, the hydrocaulus, and the root-like projections by which the stalk is attached to the substratum, the hydrorhiza. The gastrovascular space (Fig. 150) extends throughout the colony so that all the polyps are in communication with one another. A cuticular layer called the perisarc is secreted by the ectoderm of many species which gives rigidity to the whole colony: in the *Hydrocorallinae* the perisarc is calcareous and so enormously thickened that the colony has the appearance of coral. The mouth of the hydroid is terminal in position and at the summit of an elevation called the hypostome.

In very many *Hydromedusae,* the hydroid individuals are polymorphic (Fig. 162), being specialized to perform different functions.

The medusoid stage or gonosome is either a free-swimming craspedote medusa or a sessile medusoid individual or gonophore which remains attached to the parent hydroid. In the latter case it may have retained the general form of a medusa or it may be reduced to the form of a bud (sporosac) and have lost all semblance of the medusoid form. The embryo is ciliated and is called the planula: after a period of free life it attaches itself and becomes a hydroid polyp.

Most *Hydromedusae* live in the sea. *Hydra* is found in fresh water and is cosmopolitan in its distribution. *Cordylophora* is a brackish water form which also occurs in fresh water. A few medusae, *Microhydra* in Pennsylvania and Europe, *Craspedacusta* (*Limnocodium*) in America, Europe and Brazil, *Limnocnida* in Lake Tanganyika and *Holomisis* in Trinidad, occur in fresh water. The class contains about 2,000 species, grouped in 7 orders.

Key to the orders of *Hydromedusae:*

A. THE HYDROIDS.

a_1 Animals mostly in fresh water.....1. HYDRARIAE
a_2 Animals marine (rarely in fresh water).
  b_1 Colony forms a coral-like stock.....2. HYDROCORALLINAE
  b_2 Colony not coral-like.
    c_1 Colony and individual hydroid usually not minute.
      d_1 No protective cup (hydrotheca) on hydranth (Fig. 150)..3. TUBULARIAE
      d_2 Hydrotheca present (Fig. 172).....4. CAMPANULARIAE
    c_2 Colony and hydroid minute (when present).....5. TRACHOMEDUSAE
    c_3 Colony free swimming.....7. SIPHONOPHORA

B. THE MEDUSAE.

(Excluding the *Hydrocorallinae* and the *Siphonophora.*)

a_1 Rim of umbrella not scalloped.
  b_1 Gonads on manubrium.....3. TUBULARIAE (*Anthomedusae*)
  b_2 Gonads on subumbrella (sometimes also on manubrium).
    c_1 Medusae often disc-like at maturity...4. CAMPANULARIAE (*Leptomedusae*)
    c_2 Medusa usually hemispherical or elongate.....5. TRACHOMEDUSAE
a_2 Rim of umbrella scalloped.....6. NARCOMEDUSAE

Order 1. HYDRARIAE.* (The Hydras.)

Elongate, cylindrical animals 1 to 3 centimeters in length. The animal attaches itself temporarily by means of a sticky secretion at one end which may be called the foot, and can move about slowly by gliding on the foot and by a looping movement; it cannot swim. At the free end is the mouth on the conical hypostome, at the base of which is a single row of hollow tentacles. No perisarc is present. The food consists of small crustaceans and other animals which are caught by means of the nematocysts. When the animal is well fed it reproduces principally by budding, the buds often remaining attached to the parent for a while, but finally becoming separated: it also reproduces occasionally by transverse or longitudinal fission. At certain times the *Hydra* reproduces sexually and is either monœcious or unisexual. Spermatozoa are produced from specialized interstitial cells usually near the base of the tentacles which form rudimentary testes, and a single large ovum may appear in an ovary formed of interstitial cells usually near the proximal end of the body.

Fig. 148

Hydra viridissima (Süssw. F. Deut.). 1, sperm; 2, ovum.

The order contains about four genera, of which *Hydra* is the most familiar. The other genera, *Protohydra* and *Haleremita,* which are marine, and *Polypodium,* which was found on the eggs of the sturgeon in the river Volga, are apparently rare and have not been found in this country.

Hydra L. Tentacles 4 to 12 in number: 3 well established species; cosmopolitan; in fresh water.

H. viridissima Pallas (*H. viridis* L.) (Fig. 148). Green hydra. Body grass green, the color being due to the presence of *zoochlorellae* in the entoderm; tentacles short and about 6 in number; hermaphroditic: usually on water plants.

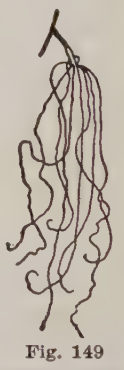

Fig. 149

Hydra oligactis (Süssw. F. Deut.).

H. oligactis Pallas (*H. fusca* L.) (Fig. 149). Brown hydra. Body brown; tentacles very long and about 8 in number; proximal end of body slender and stalk-like; unisexual: on stones, sticks, and plants.

H. vulgaris Pallas (*H. grisea* L.). Color gray, orange, or brown; proximal end of body not stalk-like; average number of tentacles 6: on stones, plants, etc.

* See "Mém. pour servir a l'Hist. d'un genre de Polyps d'eau douce," by A. Trembley, 1744. "The Development of Hydra," by G. A. Tannreuther, Biol. Bull., Vol. 14, p. 261, 1908. "Die Benennung und Unterscheidung der Hydra Arten," by A. Brauer, Zool. Anz., Vol. 33, p. 790, 1909.

Order 2. HYDROCORALLINAE.

Hydromedusans in which the polyps are colonial and have a calcified perisarc of such thickness that the colonies resemble corals. In fact, the animals were classified among the corals until Louis Agassiz in 1859 showed them to be hydromedusans allied to the *Tubulariae*. The colony is incrusted on a rock or some other object and rises erect in the form of a more or less arborescent, coral-like body in the water, being composed of a network of tubes imbedded in a thick calcareous mass. The tubes have the cellular structure characteristic of hydromedusans, the calcareous groundwork being secreted by their ectoderm. Numerous pores appear in the surface of the colony leading into cylindrical chambers from the bottom of which two kinds of polyps may project into the surrounding water; these are nutritive polyps or gastrozooids, with mouth end often provided with tentacles, and the defensive polyps or dactylozooids, without mouth and with batteries of nematocysts. The gonosomes are usually sporosacs, but in a few forms they are medusae and are produced in chambers which open to the outside through special pores.

The suborder contains 2 families and 15 genera, which are inhabitants of tropical seas. One species occurs on the Florida coast.

Family MILLEPORIDAE.

Colony very varied in form, consisting of a broad basal mass which is incrusted on the rock, and irregular, short branches which rise from it into the water; the nutritive polyps have each 4 or 5 short knobbed tentacles; the defensive polyps are also provided with tentacles; the gonosome is a free medusa with 4 or 5 rudimentary tentacles: 1 genus.

Millepora L. Each nutritive polyp is surrounded by 5 to 6 long and very contractile defensive polyps: 1 species on the Florida coast and in the West Indies.

M. alcicornis L. Pepper coral. On the coast of Florida; has unusual stinging powers.

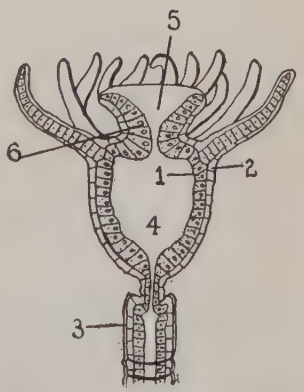

Fig. 150—A tubularian hydroid polyp (*Eudendrium*) (Hertwig). 1, entoderm; 2, ectoderm; 3, perisarc; 4, gastrovascular space; 5, mouth; 6, hypostome.

Order 3. TUBULARIAE. (Gymnoblastea; Anthomedusae.)

Mostly colonial hydromedusans in which the hydranth is without a protective cup (hydrotheca) (Fig. 150) and which produce either free

medusae or sessile medusoid buds. The medusae (Fig. 147, B) are known as *Anthomedusae* and are usually more or less bell-shaped and ocellate and bear the gonads on the manubrium. Many of them have never been traced to the hydroids which produce them: about 15 families.

Key to the families of *Tubulariae* here described:

A. THE HYDROIDS.

a_1 Hydranth without a basal whorl of tentacles, these being scattered more or less irregularly over the hydranth.
  b_1 Tentacles filiform; no free medusae.....1. CLAVIDAE
  b_2 Tentacles knobbed.....2. CORYNIDAE
a_2 Hydranth with a basal whorl and with or without distal tentacles.
  b_1 Hydranth with a basal whorl and no distal tentacles.
    c_1 Colony arborescent.
      d_1 Hypostome conical; free medusae present.....3. BOUGAINVILLIIDAE
      d_2 Hypostome trumpet-shaped; sporosacs present.....4. EUDENDRIIDAE
    c_2 Colony not arborescent, but incrusting.
      d_1 Sporosacs present and no free medusae.....5. HYDRACTINIIDAE
      d_2 Medusae present.....6. PODOCORYNIDAE
  b_2 Hydranth with both basal and distal tentacles.
    c_1 Distal tentacles knobbed.....7. PENNARIIDAE
    c_2 Distal tentacles filiform; hydranths of large size.
      d_1 Free medusae present.
        e_1 Hydranths solitary.....8. CORYMORPHIDAE
        e_2 Hydranths colonial.....9. DENDROCLAVIDAE
      d_2 Sporosacs in pendant clusters present.....10. TUBULARIIDAE

B. THE MEDUSAE.

(The 1st, 4th, 5th and 10th families produce no free medusae.)

a_1 No oral tentacles or lobes present.
  b_1 Two or 4 marginal tentacles.
    c_1 Tentacles well developed.....2. CORYNIDAE
    c_2 Tentacles rudimentary.....7. PENNARIIDAE
  b_2 One long marginal tentacle, the others short (except *Ectopleura*).
    8. CORYMORPHIDAE
a_2 Oral tentacles or lobes present.
  b_1 Marginal tentacles in 4 or 8 clusters (except *Perigonimus*).
    3. BOUGAINVILLIIDAE
  b_2 Tentacles not in clusters.
    c_1 Marginal tentacles 2 or 4.....PERIGONIMUS
    c_2 Marginal tentacles 4 or 8.....6. PODOCORYNIDAE
    c_3 Marginal tentacles numerous.....9. DENDROCLAVIDAE

FAMILY 1. CLAVIDAE.

Trophosome: colony either branching or consisting of an extensive, filiform hydrorhiza from which rise the polyps; hydranths elongate and bearing numerous filiform tentacles irregularly placed. Gonosome: gonophores in clusters either just below the tentacles or on special branches or even rising independently from the hydrorhiza, forming sporosacs and never medusae: about 5 genera.

Key to the genera of *Clavidae* here described:

a_1 Colony not branching; polyps rising from a filiform hydrorhiza.
b_1 Sporosacs borne on hydranths.....1. CLAVA
b_2 Sporosacs spring from hydrorhiza.....2. RHIZOGETON
a_2 Colony branching.....3. CORDYLOPHORA

1. CLAVA Gmelin. Simple unbranched hydranths rise from a filiform hydrorhiza; this is protected by a perisarc which extends a short distance up the hydranth; sporosacs in clusters at the base of the tentacles: 5 species.

C. leptostyla Agassiz (Fig. 151). Hydranths reddish in color, about 2 cm. long, with about 20 tentacles; male sporosacs pink, female purple: common in shallow water on fucus, piles, etc., from Long Island Sound to Labrador; California.

Fig. 151—*Clava leptostyla* (Nutting).

2. RHIZOGETON Agassiz. Similar to *Clava*, except that the sporosacs arise from the hydrorhiza on short stalks: 1 species.

R. fusiformis Ag. Hydranth about 8 mm. high, with 12 tentacles; sporosacs shorter and invested with the perisarc: in rock pools in Massachusetts Bay.

3. CORDYLOPHORA* Allman. Colony profusely branching, the hydranths with scattered filiform tentacles being at the ends of the branches; sporosacs ovate, springing from the branches; with a definite perisarc: 2 species.

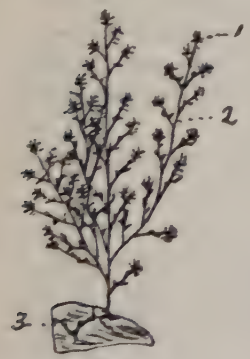

Fig. 152

Fig. 153

Fig. 152—*Cordylophora lacustris* (Süssw. F. Deut.). 1, hydranth; 2, hydrocaulus; 3, hydrorhiza. Fig. 153—*Syncoryne mirabilis* (Agassiz).

C. lacustris All. (Fig. 152). Colony about 20 to 30 mm. high; hydranth with 10 to 20 tentacles: on rocks, eel grass, etc., in brackish and fresh water, being one of the very few fresh-water cœlenterates; Rhode Island; Massachusetts; Illinois; sometimes rather common; Europe.

FAMILY 2. CORYNIDAE.

Trophosome: colony branched or not, with long, slender hydrocaulus and cylindrical hydranths bearing numerous knobbed tentacles

* See "Hydroids in the Illinois River," by F. Smith, Biol. Bull., Vol. 18, p. 67, 1910.

irregularly placed. Gonosome: gonophores usually among the basal tentacles and producing either free-swimming or attached medusae with 4 radial canals and 4 tentacles: numerous genera.

Key to the genera of *Corynidae* here described:

a_1 Hydroid branched; medusa with 4 long, marginal tentacles....1. SYNCORYNE
a_2 Hydroid branched; medusa with 4 short knobbed marginal tentacles. 2. DIPURENA
a_3 Hydroid not branched; medusa with 2 long and 2 rudimentary marginal tentacles.....3. GEMMARIA

1. SYNCORYNE Ehrenberg. Hydroid colony 15 mm. high and branched and with definite perisarc and an elongate, cylindrical hydranth; medusa with an ocellus at the base of each tentacle: 16 species.

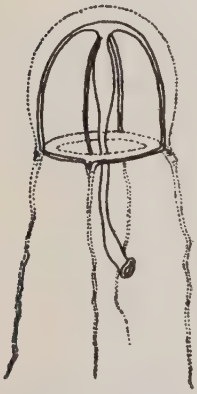

Fig. 154—*Syncoryne mirabilis;* medusa (Hargitt).

S. mirabilis Agassiz (Fig. 153). Hydroid colony attached to seaweed, shells, etc., in shallow water, from Martha's Vineyard to Greenland, also in California; medusoid in 2 varieties, one, which was first described as *Sarsia mirabilis,* free-swimming, developing in early spring, 7 mm. high and 4 mm. in diameter, with 4 long, marginal tentacles and a long manubrium extending beyond the velum (Fig. 154); the other, a sporosac, with rudimentary tentacles, and without ocelli or mouth.

2. DIPURENA McCrady. Hydroid like *Syncoryne;* medusae with 4 stout marginal tentacles the ends of which are knobbed, and a long manubrium with constrictions, often extending beyond the velum: 6 species.

D. strangulata McCr. (Fig. 155). Medusa very transparent, 3 mm. wide, 4 mm. high, ovoid in shape: common at Woods Hole; South Carolina.

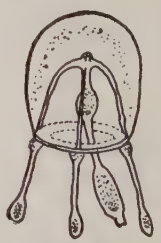

Fig. 155
Dipurena strangulata (Hargitt).

3. **GEMMARIA** McCrady. Hydroid like *Syncoryne* but unbranched, the hydranth rising from a creeping hydrorhiza; medusa with 2 marginal tentacles, each of which bears long-stalked nematocysts, and with mouth without marginal lobes: several species.

G. gemmosa McCr. Hydroid on *Mytilus* shells, etc.; adult medusa 6 mm. in diameter, almost spherical and with 2 tentacles; no ocelli: Vineyard Sound and southwards.

FAMILY 3. BOUGAINVILLIIDAE.

Trophosome: colony branching with distinct, often annulated perisarc; hydranth with a single whorl of filiform tentacles. Gonosome: a

free-swimming medusa which is usually borne on the hydrocaulus and has 4 radial canals; marginal tentacles either single or in clusters, and 4 or 8 manubrial gonads: about 19 genera.

Key to the genera of *Bougainvilliidae* here described:

a_1 Hydroid colony arborescent; medusa with tentacles in clusters.
b_1 Medusa with tentacles in 4 clusters.
c_1 Medusa without short knobbed tentacles; hydroid arborescent. 1. BOUGAINVILLIA
c_2 Medusa with a pair of short knobbed tentacles at each cluster..5. NEMOPSIS
b_2 Medusa with tentacles in 8 clusters; hydroid like Bougainvillia..4. RATHKEA
a_2 Hydroid colony with creeping hydrorhiza; medusa with only 2 long tentacles.
b_1 Four short oral lobes.....2. PERIGONIMUS
b_2 Four long oral lobes.....3. STOMOTOCA

1. BOUGAINVILLIA Lesson. Trophosome: colony arborescent with a dense perisarc, hydranth with conical hypostome. Gonosome: medusa globular, with branching oral tentacles and 4 pairs at first and later 4 groups of marginal tentacles: 20 species.

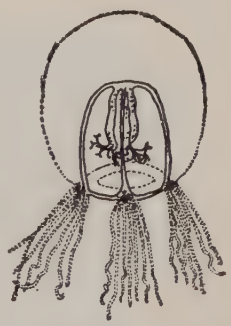

Fig. 156—*Bougainvillia carolinensis* (Hargitt).

B. carolinensis (McCrady) (Fig. 156). Colony may be 25 cm. high, usually 7 to 12 cm.; hypostome conspicuous; tentacles about 12; medusa with brick-red manubrium and black ocelli, 4 mm. in diameter: Cape Cod and southward; common on fucus, piles, etc.

Fig. 157

Bougainvillia superciliaris (Agassiz).

B. superciliaris Agassiz (Fig. 157). Colony 5 cm. high or less; hypostome inconspicuous; tentacles 15 to 20; medusa with yellowish manubrium and black ocelli, 10 mm. in diameter: Newport to Greenland; on fucus and shells; Europe.

2. PERIGONIMUS Sars. Trophosome: colony branching a little and rising from a reticulated hydrorhiza with a gelatinous perisarc and conical hypostome. Gonosome: medusa with 2 or 4 marginal tentacles; no ocelli: 10 species.

P. jonesi Osborn and Hargitt. Hydroid colony, 10 mm. high or less; hydranth with 16 tentacles; medusa hemispherical with an apical projection, 2 mm. high and broad, with 2 long tentacles and 2 additional tentacular bulbs; manubrium short, squarish, with 4 oral lobes: on spider crabs (*Libinia*) at Cold Spring Harbor, L. I.

3. **Stomotoca** Agassiz. Trophosome like *Perigonimus*. Gonosome: medusa more or less conical with an apical projection; with 2 long marginal tentacles and a squarish manubrium and 4 oral lobes and the often very large gonads on the side: 6 species.

Fig. 158 *Stomotoca apicata* (Hargitt).

S. apicata (McCrady) (Fig. 158). Hydroid form unknown; entoderm of manubrium greenish in color in the male and brownish in the female; base of the tentacles purplish or yellowish; size 4 mm. by 3 mm.: Florida to Vineyard Sound; Europe.

S. rugosa Mayer. Similar to preceding, but with 14 rudimentary marginal tentacles together with the 2 long ones; base of the tentacles and manubrium brick red; 5 mm. high: common at Newport, R. I., and southwards.

4. **Rathkea** Brandt (*Lizzia* Forbes). Trophosome unknown. Gonosome: medusa subconical with marginal tentacles in 8 clusters of 3 to 5 each; young with only 4 tentacles; manubrium buds off young medusae; 4 branching oral tentacles; no ocelli: 8 species.

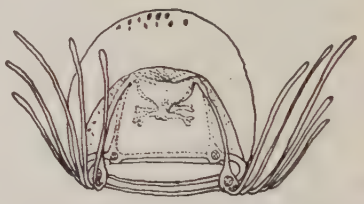

Fig. 159—*Rathkea grata* (Hargitt).

R. grata A. Agassiz (Fig. 159). Medusa 3 to 6 mm. high, transparent: Massachusetts Bay to Newport, R. I.; often common.

Fig. 160 *Nemopsis bachei* (Mayer).

5. **Nemopsis** Agassiz. Trophosome like *Bougainvillia* except that the medusae arise from the hydranths. Gonosome: medusa like *Bougainvillia* but with a pair of short-knobbed tentacles directed upwards from each group of long tentacles and with gonads extending on to the subumbrella: 2 species.

N. bachei Ag. (Fig. 160). Medusa 6 to 10 mm. high: Florida to Vineyard Sound; common.

Family 4. EUDENRIIDAE.

Trophosome: colony branching, rising from a reticulated hydrorhiza; perisarc distinct and variously annulated; hydranth with trumpet-shaped hypostome (Fig. 150) and a single whorl of filiform tentacles. Gonosome: no free medusae; male sporosacs in a whorl just beneath, and the female sporosacs usually just above the tentacles and occasionally on the hydrocaulus: 1 genus.

Eudendrium Ehrenberg. With the characters of the family: about 8 American species.

Key to the species of *Eudendriidae* here described:

a_1 Colony large (8 to 15 cm. high).
b_1 Branches annulated at their base only.....E. RAMOSUM
b_2 Branches completely annulated.....E. DISPAR
a_2 Colony small (less than 3 cm. long).....E. TENUE

E. ramosum (L.) (Figs. 150 and 161). Colony profusely branched, 10 to 15 cm. high, with symmetrical branches; tentacles about 20; male sporosacs reddish and in moniliform clusters; female sporosacs orange and pyriform: abundant on piles, rocks, etc., in shallow water from North Carolina to Labrador; Pacific Coast; Europe.

E. dispar Agassiz. Colony less profusely branched than above,

Fig. 161

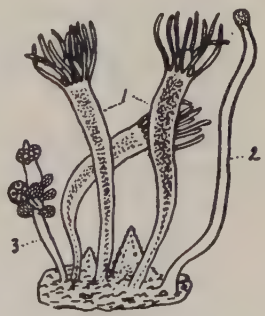

Fig. 162

Fig. 161—*Eudendrium ramosum* (from Hargitt). Fig. 162—*Hydractinia echinata* (McMurrich). 1, feeding hydranth; 2, defensive hydranth; 3, reproductive hydranth.

6 to 10 cm. high; tentacles about 28; sexes distinct: in deeper water from Vineyard Sound to Bay of Fundy.

E. tenue A. Agassiz. Colony irregularly branched, 25 mm. in height; male sporosacs moniliform and pink; female sporosacs orange and scattered over the hydrocaulus: on seaweed, etc., in shallow water from Buzzard's Bay to Bay of Fundy; not abundant.

FAMILY 5. HYDRACTINIIDAE.

Trophosome: colony incrusting, the polyps rising separately from an incrusted, spiny hydrorhiza to which the perisarc is confined, and polymorphic, consisting of 3 types of individuals: (1) feeding hydranths, which have a single whorl of tentacles; (2) reproductive individuals, bearing clusters of sporosacs; and (3) defensive individuals usually without tentacles but with numerous nematocysts at the apex. Gonosome: sporosacs and no free medusae present: 1 genus.

Hydractinia Van Beneden. With the characters of the family: 2 American species.

H. echinata Fleming (Fig. 162). Colony 10 mm. high; reproductive individuals without tentacles: usually on the shells of hermit crabs but also on stones, fucus, piles, etc.; very common on Atlantic coast; Europe.

H. milleri Torrey. Colony 5 mm. high; reproductive individuals with tentacles: California.

Family 6. PODOCORYNIDAE.

Trophosome: like that of *Hydractiniidae*. Gonosome: free medusae present, each with 4 radial canals and 4 or 8 or more marginal tentacles: several genera.

Key to the genera of *Podocorynidae* here described:

a_1 Medusa with long tentacles, hydroid on *Limulus*, shells of hermit crabs, etc. ..... 1. Podocoryne

a_2 Marginal tentacles of medusa rudimentary; hydroid on *Nassa*... 2. Stylactis

1. Podocoryne Sars. Trophosome: like *Hydractinia*. Gonosome: medusa globular with 8 or more rather thick tentacles: 11 species.

P. carnea Sars (Fig. 163). Medusa very transparent, 3 mm. high, with 4 marginal tentacles in the young and 24 to 32 in the adult; manubrium reddish with 4 oral tentacles: hydroid on *Limulus*, crabs, rocks, etc.

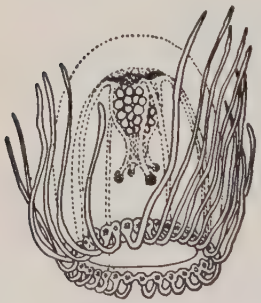

Fig. 163.—*Podocoryne carnea* (Mayer).

P. fulgurans (A. Agassiz). Medusa 1 mm. high, hemispherical, with 8 marginal and 4 oral tentacles; manubrium buds off young medusae: North Carolina to Massachusetts Bay; common; often brightly phosphorescent.

2. Stylactis Allman. Trophosome: colony consisting of very long, slender hydranths rising from a reticular base. Gonosome: a sporosac in the European species, but in the American a medusa with rudimentary tentacles: several species, 2 American.

S. hooperi Sigerfoos. Hydranths 20 mm. long with 18 to 25 tentacles; medusa globular, 1 mm. in height with 8 rudimentary, marginal and no oral tentacles and borne on specialized hydranths, just below the tentacles; no ocelli: Long Island and Vineyard Sounds, on *Nassa obsoleta*.

Family 7. PENNARIIDAE.

Trophosome: colony regularly branching; hydranth with a basal whorl of 10 to 12 filiform tentacles and also a number of short knobbed

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tentacles on the hypostome. Gonosome: either a free or a sessile medusa with 4 radiating canals and 4 rudimentary tentacles: about 7 genera.

Pennaria Oken. With the characters of the family: about 6 species.

P. tiarella (Ayres) (Fig. 164). The bright pink hydroid colony may be 15 cm. in height, and is attached to piles, rocks, or seaweed in shallow water; medusoid buds on the side of the hydranth; medusa

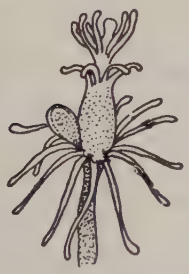

Fig. 164

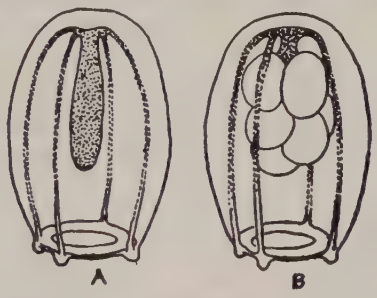

Fig. 165

Fig. 164—*Pennaria tiarella;* a hydranth with a medusoid bud (Hargitt). Fig. 165—*Pennaria tiarella;* a male (A) and a female (B) medusa (Hargitt).

(Fig. 165) an elongated bell about 2 mm. long with 4 rudimentary tentacles; the medusa is free-swimming chiefly during midsummer, the greater part of the year it is more or less sessile: common from Maine to Florida.

Family 8. CORYMORPHIDAE.

Trophosome: hydranths solitary and of large size with a basal and several distal whorls of filiform tentacles; medusae produced just within the basal tentacles. Gonosome: free medusae with 4 radial canals and 1 to 4 marginal tentacles, one of which is longer than the rest: several genera.

Fig. 166—*Corymorpha pendula* (Agassiz).

1. Corymorpha Sars. Large solitary polyps with a soft striated outer surface and no well-defined perisarc, rooted by filamentous processes: 5 species.

C. pendula Agassiz (Fig. 166). Polyp pendant, 3 to 10 cm. high and bright pink; medusa bell-shaped with a projection at the apex, with 1 large and 1 to 3 rudimentary marginal tentacles; manubrium extends

to the velum; length 6 mm.: common from Vineyard Sound to Gulf of St. Lawrence in 8 to 30 fathoms.

2. **Hybocodon** Agassiz. Trophosome: polyp large, solitary, with a well-defined perisarc and hydrorhiza; hydranth with a basal and 2 distal whorls of filiform tentacles; just within the base of the former medusae are budded off: 2 species.

H. prolifer Agassiz (Fig. 167). Orange-colored hydroids 4 cm. high, with longitudinally striated perisarc which is annulated just below the hydranth; medusa hemispherical and asymmetrical, with 5 medidional orange-colored bands at maturity and with 1 to 3 long marginal tentacles, from the thick base of which secondary medusae bud: on rocks in clear water from Vineyard Sound to Massachusetts Bay; not common.

3. **Ectopleura** Agassiz. Trophosome: hydroid like *Tubularia,* being indistinguishable when without gonophores. Gonosome: free medusae,

Fig. 167

Fig. 168

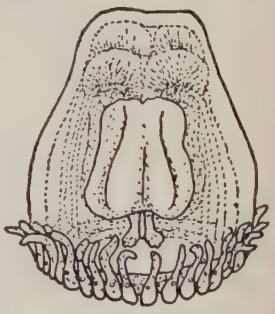

Fig. 169

Fig. 167—*Hybocodon prolifer* (Mayer). Fig. 168—*Ectopleura ochracea* (Hargitt). Fig. 169—*Turritopsis nutricula* (Mayer).

rather elongate, with 2 or 4 tentacles from the base of which lines of nematocysts extend on the surface of the bell to its apex: 3 species.

E. ochracea A. Agassiz (Fig. 168). Medusa about 3 mm. in height with a large manubrium and 8 longitudinal bands of nematocysts on exumbrella: Cape Cod to South Carolina; common.

Family 9. DENDROCLAVIDAE.

Trophosome: colony branching, with an elongate hydranth at the end of each branch bearing 18 to 20 short filiform tentacles scattered over it. Gonosome: a free-swimming medusa produced below the hydranth: 2 genera.

1. **Turritopsis** McCrady. Hydroid form as above; medusa hemispherical, with 8 to 70 equidistant tentacles; 4 reddish gonads: 1 species.

T. nutricula McCrady (Fig. 169). Medusa 4 to 5 mm. in diameter: Cape Cod to Florida; often common.

Family 10. TUBULARIIDAE.

Trophosome: polyps solitary or colonial, of large size and bright pink in color; hydranths with a basal and a distal whorl of filiform tentacles. Gonosome: medusoids remain attached to the polyp, being suspended from long-branched stalks above the basal tentacles and varying in form from sporosacs to perfect medusae; no free medusae; the female medusoids produce peculiar free-swimming hydroid-like bodies called actinules: 1 genus.

Tubularia L. With the characters of the family: about 20 species.

Key to the species of *Tubularia* here described:

a_1 Polyps unbranched, in groups of 4 to 8; medusoids with distinct radial canals.....T. COUTHOUYI
a_2 Polyps branched; often no distinct radial canals in medusoids.
b_1 Hydranth with collar.....T. LARYNX
b_2 No collar present.
c_1 Hydranth large; often in muddy water.
d_1 Sporosac with conical apical process.....T. SPECTABILIS
d_2 Female sporosac with flattened apical process.....T. CROCEA
c_2 Hydranth small; often in clear water.....T. TENELLA

T. couthouyi Agassiz (Fig. 170). Individuals unbranched, 7 to 15 cm. high; hydranth often expanding 20 mm. or more, with a basal whorl of 30 to 40 tentacles; medusoid with distinct radial canals: on sandy bottoms in shallow or brackish water, in clusters of 5 to 10 individuals; New England coast.

Fig. 170—*Tubularia couthouyi* (Agassiz).

T. larynx Ellis and Solander. Individuals somewhat branched and extensively annulated and living in clusters, 2 to 5 cm. high; a collar-like expansion just below hydranth, the latter with 16 to 20 basal tentacles; female medusoid with a conical apical process and no distinct radial canals: in shallow water from Cape Cod northwards; California; Europe; on rocky and shelly bottoms.

T. spectabilis (Ag.). Colony irregularly branched, sparsely annulated, and 8 to 10 cm. high, growing in a tangled mass; 20 basal tentacles: in shallow water from Rhode Island to Bay of Fundy.

T. tenella (Ag.). Colony 25 to 40 mm. high and like preceding form but more loosely branched: in tide pools and the open ocean; Massachusetts Bay to Bay of Fundy.

Fig. 171—*Tubularia crocea* (Agassiz). A, a colony; B, a single hydranth.

T. (*Parypha* Ag.) **crocea** (Ag.) (Fig. 171). Colonies growing in dense tufts of long tangled stems of from 8 to 10 cm. in height; sparingly branched; basal tentacles 20 to 24; apical process of the female sporosac flattened: common on piles, docks, etc., in shallow water from Boston southwards; California.

ORDER 4. **CAMPANULARIAE.*** (CALYPTOBLASTEA; LEPTOMEDUSAE.)

Colonial hydromedusans with two kinds of polyps (Fig. 172), the hydranths or the nutritutive polyps and the blastostyles or the reproductive polyps. The perisarc does not end at the base of the polyp, as in the tubularians, but continues over it, forming, in the case of the hydranth a protective cup called the hydrotheca and in the case of the blastostyle a cylindrical capsule called a gonangium or a gonotheca. In some species the open end of the hydrotheca may be closed by projections or valves which form an operculum (Fig. 173); in some species also the blastostyle projects out of the mouth of the gonangium and forms a large capsule or brood chamber in which the eggs develop, called the acrocyst (Fig. 178). The hydranth has never more than a single whorl of tentacles and can in most cases be retracted within its hydrotheca or extended beyond it. The blastostyle cannot usually be extended beyond its gonangium and produces within it the gonophores; these constitute

Fig. 172—A campanularian hydroid (from Hegner). 1, hydranth; 2, hydrotheca; 3, blastostyle; 4, gonangium.

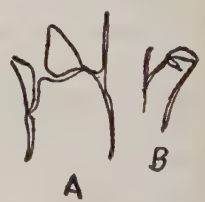

Fig. 173

Campanularian opercula (Nutting). A, two-valved operculum; B, one-valved operculum.

* See "The Leptomedusae of the San Diego Region," by H. B. Torrey, Uni. of Cal. Pub., Vol. 6, p. 11.

the medusoid generation and may either be liberated as free medusae, or, remaining in the gonangium, produce the sexual products there, which escape from the gonangium as free larvae. The medusae (Fig. 191) are known as *Leptomedusae* and (except in the *Thaumantiidae*) have lithocysts and not ocelli as sense organs: they bear the gonads beneath the radial canals on the subumbrella: about 8 families.

Key to the families of *Campanulariae* here described:

A. THE HYDROIDS.

a_1 Hydrotheca sessile, *i. e.*, not joined to the stem by a stalk; gonangium contains sporosacs.
  b_1 Hydrothecae in 2 rows (except *Hydrallmania*) either opposite to each other on the stem or not.....1. SERTULARIIDAE
  b_2 Hydrothecae in a single row on the stem.....2. PLUMULARIIDAE
a_2 Hydrotheca stalked and bell-shaped.
  b_1 The gonophores are sporosacs.....3. CAMPANULARIIDAE
  b_2 The gonophores are medusae; hydroid forms very little known except in the genera *Obelia*, *Clytia*, and *Laodicea*.
4. EUCOPIDAE. 5. ÆQUOREIDAE. 6. THAUMANTIIDAE

B. THE MEDUSAE.

The 1st, 2nd, and 3d families produce only sporosacs and no free medusae.
a_1 Four simple radial canals; lithocysts and no ocelli present.....4. EUCOPIDAE
a_2 Radial canals numerous (8-100).....5. ÆQUOREIDAE
a_3 Radial canals 4 or 8; ocelli present and no lithocysts..6. THAUMANTIIDAE

FAMILY 1. SERTULARIIDAE.*

Trophosome: colony usually branching; hydrothecae sessile (not stalked), almost all with opercula (Fig. 173) and forming two rows along opposite sides of the hydrocaulus (except *Hydrallmania*). Gonosome: gonangia much larger than the hydrothecae, there being only a few in the colony, and occurring only at certain times of the year; each gonangium contains a blastostyle which produces planulae; no free medusae: about 15 genera and 135 American species.

Key to the genera of *Sertulariidae* here described:

a_1 Hydrothecae in two rows.
  b_1 Hydrothecae exactly opposite each other.
    c_1 Operculum in 2 pieces (Fig. 173, A).....1. SERTULARIA
    c_2 Operculum in 1 piece (Fig. 173, B).....3. DIPHASIA
  b_2 Hydrothecae alternate or subalternate to each other.
    c_1 Hydrothecae stand out from the stem.
      d_1 Hydrotheca with toothed margin; operculum of 3 or 4 pieces.
2. SERTULARELLA
      d_2 Hydrotheca with smooth margin; operculum of one piece..4. ABIETINARIA
    c_2 Hydrothecae closely pressed against the stem.....5. THUIARIA
a_2 Hydrothecae in one row, the openings turning alternately to the right and left.....6. HYDRALLMANIA

* See "American Hydroids, Part II, The Sertularidae," by C. C. Nutting, U. S. Nat. Mus. Spec. Bull., No. 4, 1904.

1. Sertularia L. Hydrothecae in pairs along the stem, the members of a pair being exactly opposite each other; operculum paired (Fig. 173, A); gonangia have plain margins and are of simple form: about 20 American species.

S. pumila L. (Fig. 174). A simple or more or less branched colony 1 to 5 cm. high attached by a creeping hydrorhiza, the stem being divided into short internodes, each bearing a pair of hydrothecae; gonangia oval, sessile and often bearing acrocysts, the male gonangium being somewhat more slender than the female: common on fucus, etc., between tide lines, from New Jersey to the Arctic Ocean; California; Europe.

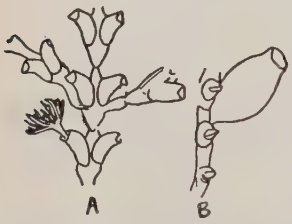

Fig. 174—*Sertularia pumila* (Nutting). A, portion of a colony; B, a gonangium.

2. Sertularella Gray. Similar to preceding genus, but differs from it in that the hydrothecae are alternate on the hydrocaulus and not opposite, and possess a prominent operculum composed of several pieces; gonangium usually deeply annulated: about 50 American species.

Key to the species of *Sertularia* here described:

a_1 Margin of hydrotheca with 4 slight teeth.
  b_1 Hydrotheca annulated.
    c_1 Annulations only on upper side.....S. GAYI
    c_2 Annulation complete.....S. RUGOSA
  b_2 Hydrotheca smooth.....S. POLYZONIAS
a_2 Margin of hydrotheca with 3 teeth.....S. TRICUSPIDATA

S. rugosa (L.) (Fig. 175). A small colony 2 cm. high, either unbranched or little branched and with annulated stem; hydrothecae crowded, annulated and with 4 marginal teeth; gonangia large, annulated and with four-toothed aperture: New England coast; Puget Sound; Europe.

S. gayi (Lamouroux). Colony attaining a height of 15 cm. and with paired or alternate branches; hydrothecae wrinkled or partially annulated and with a four-toothed aperture; gonangia elongate, ovate, tapering towards both ends, annulated in upper portion: Atlantic coast; Europe.

Fig. 175 *Sertularella rugosa* (Kingsley).

S. polyzonias (L.). Irregularly branching colony attaining a height of 12 cm.; hydrotheca smooth, with 4 teeth; gonangium deeply annulated and with 4 teeth: Atlantic and Pacific coast; cosmopolitan; common.

S. tricuspidata (Alder). Colony 12 cm. high or less and slender with alternate branches; hydrotheca smooth, with 3 teeth; gonangium

with deep annulations and a bowl-shaped orifice: New England coast; common; north Pacific coast; Europe.

3. **Diphasia** Agassiz. Colony more or less branching, jointed, the hydrothecae in pairs opposite each other and standing out from the stem; a single operculum present (Fig. 173, B); gonangia dimorphic, the female being the larger and often annulated, and with a brood pouch in its distal half, the male with a central tubular orifice and 4 spines: 10 American species.

Fig. 176—*Diphasia fallax* (Hargitt).

D. fallax (Johnston) (Fig. 176). Colony about 8 cm. high, with simple branching, the ends of the branches being often tendril-like; gonangia elongate; female gonangia oval, deeply cleft into 4 segments: Massachusetts Bay to Bay of Fundy; Europe.

D. rosacea (L.). Colony delicate, about 8 cm. high, branching alternately; gonangium with longitudinal ridges terminating, in the male, in the teeth which surround the orifice: northerly New England coast; Europe; common.

4. **Abietinaria** Kirchenpauer. Hydrothecae flask-shaped and alternate or subalternate with operculum of one piece on the side next to the stem and with smooth margin: 16 species.

Fig. 177
Abietinaria abietina (Kingsley).

A. abietina (L.) Sea-fir (Fig. 177). Colony large and bushy, being sometimes 30 cm. high or more, with alternate branching, with very large hydrothecae and relatively small gonangia: from Vineyard Sound to Labrador; north Pacific; Europe.

5. **Thuiaria** Fleming. Hydrothecae alternating with each other, more than a pair to an internode and closely applied to the stem, which is jointed: 20 species.

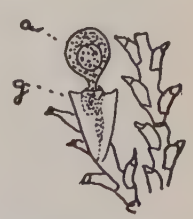

Fig. 178—*Thuiaria argentea* (Kingsley). g, gonangium; a, acrocyst.

T. thuja (L.). Colony very rigid, sometimes 25 cm. in height, zigzag in shape and annulated near the base; perisarc very dark in color; gonangia smooth and pyriform: in shallow water on northerly New England coast; Pacific coast; Europe.

T. argentea (L.) (Fig. 178). A large bushy colony, often 20 or 30 cm. high, branching alternately or dichotomously; gonangia broad, tapering towards the base, with a circular aperture and usually 2 spines: very

common; New Jersey to the Arctic Ocean from low-water mark to 100 fathoms, usually in rather deep water; Pacific coast; Europe.

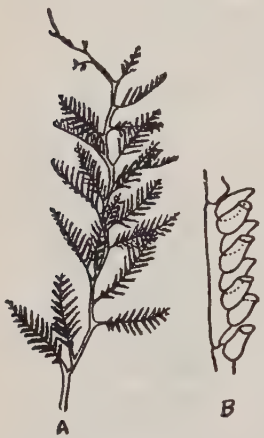

Fig. 179—*Hydrallmania falcata* (Hargitt). A, colony; B, branch with hydranths.

T. cupressina (L.). A slender, elongated colony, often 20 cm. high, branching alternately and dichotomously; gonangia elongate with a prominent spine at each side of the aperture: same habitat as the preceding but less abundant.

6. Hydrallmania Hincks. Hydrothecae in a single row projecting out from the hydrocaulus alternately to the right and the left; colony pinnately branching: 3 species.

H. falcata (L.) (Fig. 179). Colony often 30 cm. high, slender, rather rigid and with simple branching; on each branch the secondary branches are very regular and feather-like; gonangia ovate and simple: on stones, shells, etc., on New England coast and in Long Island Sound; Puget Sound; Europe.

Family 2. PLUMULARIIDAE.*

Trophosome: usually a branched colony with sessile hydranths, which are borne in a row on small branches called hydrocladia (Fig. 180); between the hydranths and on the main stem and branches are nematophores, small specialized defensive polyps, each of which consists of a hydrotheca and an elongated body armed with nematocysts. Gonosome: gonangia large, the blastostyles producing planulae and never medusae: about 43 genera and over 300 species, being a quarter of all known hydroids; about 100 species occur along the Atlantic coast and in the West Indies.

Key to the genera of *Plumulariidae* here described:

a_1 Gonangia not protected by special branchlets; nematophores trumpet-shaped and movable.
  b_1 Hydrocladia do not branch.
    c_1 Colony not dichotomously branched; the hydrocladia arranged in whorls or scattered along the stem.....1. Antennularia
    c_2 Branching dichotomous; hydrocladia all arise from the upper side of branches.....2. Monostæchas
  b_2 Hydrocladia forked.....3. Schizotricha
a_2 Gonangia protected by special branchlets; nematophores immovable. 4. Cladocarpus

* See "American Hydroids, Part I, The Plumularidae," by C. C. Nutting, U. S. Nat. Mus. Spec. Bull. No. 4, 1900.

1. **Antennularia** Lamarck. Main stem of colony simple or sparsely branched and attached by a massive hydrorhiza; hydrotheca cup-shaped; gonangia borne in the axils of the branches: 6 American species.

A. antennina (L.) (Fig. 180). Colony a dense cluster of upright stems, often 20 cm. high, obscurely jointed, each internode bearing a whorl of fine branches (hydrocladia) on which are the hydranths and the nematophores; gonangia ovate and of large size, in the axils of the hydrocladia: from Martha's Vineyard to Bay of Fundy in 6 to 60 fathoms; Europe.

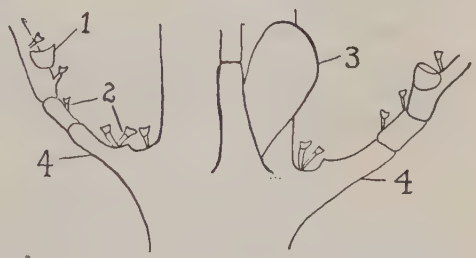

Fig. 180—*Antennularia antennina* (Nutting). 1, hydranth; 2, nematophore; 3, gonangium; 4, hydrocladium.

2. **Monostæchas** Allman. Colony branching dichotomously and attaining a height of 15 cm.; hydrocladia springing all from the upper side of the main branches: 1 American species.

M. quadridens (McCrady). From Martha's Vineyard southwards.

3. **Schizotricha** Allman. Colony usually a cluster of simple stems; hydrocladia arranged pinnately and branched in mature specimens: 4 American species.

S. tenella (Verrill). Colony branching dichotomously and attaining a height of 5 cm.; stem divided alternately into longer and shorter

Fig. 181

Fig. 182

Fig. 183

Fig. 181—*Schizotricha gracillima* (Nutting). Fig. 182—*Cladocarpus flexilis* (Nutting). Fig. 183—*Halecium halecinum* (Hargitt).

internodes, the latter bearing each a hydrocladium; gonangium cornucopia-shaped: Long Island and Vineyard Sounds, in shallow water, often on piles.

S. gracillima (G. O. Sars) (Fig. 181). Colony about 5 cm. high; branches divided into regular internodes, each bearing a hydrocladium: New England coast; Europe.

4. **Cladocarpus** Allman. Colony usually branched; hydrocladia not branched; gonangia borne on the stem at the base of the hydrocladia and protected by special branchlets armed with nematophores: 15 American species.

C. flexilis Verrill (Fig. 182). Colony up to 20 cm. long and slender; hydrotheca long and cylindrical, lying close to the hydrocladium; protecting branchlets of the gonangia branched like deer's horns: in moderately deep water along the Atlantic coast; common.

Family 3. CAMPANULARIIDAE.

Trophosome: either a branched or simple colony on which are bell-shaped and usually stalked hydrothecae; hypostome trumpet-shaped. Gonosome: gonangium large, the blastostyle producing planulae and never free medusae: about 33 genera.

Key to the genera of *Campanulariidae* here described:

a Hydrotheca rudimentary, the hydranth not being entirely retracted into it.....1. Halecium
a_2 Hydrotheca not rudimentary.
b_1 Blastostyle does not project from the gonangium.
c_1 Stem not completely annulated.
d_1 Gonangium without acrocyst, colony not parasitic.....2. Campanularia
d_2 Gonangium with acrocyst; colony parasitic on other hydroids, etc. 3. Calycella
c_2 Stem completely annulated.....4. Operculatella
b_2 Blastostyle projects from the gonangium.....5. Gonothyrea

1. **Halecium** Oken. Branching colonies with creeping hydrorhiza; the hydrothecae are more or less rudimentary, being shallow and disc-like or funnel-shaped, the margin often with a circle of dots, into which the hydranths can be only partially retracted: numerous species.

H. halecinum (L.) (Fig. 183). Colony 10 to 20 cm. high, rigid; hydrothecae alternate on the stem, cylindrical, often annulated; gonangia appear in a row, the male gonangium slender and club-shaped, the female rather irregular in shape with broad distal end and a terminal aperture: New Jersey to Labrador; in shallow water; Puget Sound to Alaska; Europe.

2. **Campanularia** Lamouroux. Colony either branched or simple, with bell-shaped hydrothecae, which are without operculum, and with or without marginal teeth: many species.

Key to the species of *Campanularia* here described:

a_1 Colony not branched, the hydranths rising separately from hydrorhiza.
  b_1 Margin of aperture of hydrotheca not toothed.....C. POTERIUM
  b_2 Margin toothed.
    c_1 Teeth square at top.....C. HINCKSI
    c_2 Teeth very shallow, the margin being sinuous.....C. VOLUBILIS
a_2 Colony branched.
  b_1 Colony large, over 10 cm. high.
    c_1 Margin of aperture toothed.....C. VERTICILLATA
    c_2 Margin of aperture not toothed.....C. AMPHORA
  b_2 Colony small, under 3 cm. high.....C. FLEXUOSA

C. poterium (Agassiz). Colony unbranched, with the hydranths at the end of long, completely annulated stalks, which rise separately from the hydrorhiza; aperture of hydrotheca not toothed; hydranth with 24 tentacles; gonangia slender and ovate, rising from the hydrorhiza: Vineyard Sound to Labrador; low-water mark to 30 fathoms, common on seaweed; Europe.

Fig. 184
Campanularia hincksi (Kingsley).

C. hincksi Alder (Fig. 184). Colony unbranched, the hydranths at the end of long and partially annulated stalks which rise separately from the hydrorhiza; aperture of hydrotheca with 12 square-topped teeth; gonangia on short stalks and annulated: from Vineyard Sound to Maine, on stones and shells; southern California; Europe.

C. volubilis (L.). Colony unbranched, the hydranths at the end of long completely annulated stalks which rise separately from the hydrorhiza; aperture of hydrotheca with 10 shallow-rounded teeth; gonangia rise from the hydrorhiza: from Vineyard Sound to Greenland; low-water mark to 100 fathoms; common; Pacific coast; Europe.

Fig. 185—*Campanularia flexuosa* (Hargitt).

C. verticillata (L.). Colony branched, attaining a height of 12 cm.; hydrothecae with a toothed aperture borne on long, partially annulated stalks which form whorls around the stem: Long Island Sound to Maine, in 4 to 45 fathoms; Alaska; Europe.

C. amphora (Agassiz). Colony branched, attaining a height of 15 cm.; hydrothecae with untoothed aperture and with a swollen stalk; hydranth with 30 tentacles; gonangia truncate: from Long Island Sound to Gulf of St. Lawrence; common.

C. flexuosa (Hincks) (Fig. 185). Colony 25 mm. high, branched irregularly; stem annulated near the base of the branches; hydrothecae

with untoothed aperture and with annulated stalks; gonangia large: Long Island Sound to Labrador, on piles, etc., abundant towards the north; Europe.

3. **Calycella** Hincks. Hydrorhiza parasitic on other hydroids, *Bryozoa,* etc., and sending forth short annulated stalks bearing elongate cylindrical hydrothecae which have opercula; gonangium oval, rising from the hydrorhiza and bearing a globular acrocyst.

Fig. 186—*Gonothyrea loveni* (Hargitt).

C. syringa (L.). Hydrotheca longer than its stalk: Long Island sound to Maine; common; Pacific coast; Europe.

4. **Operculatella** Hincks. Stem annulated throughout and sparsely branched or unbranched; hydrotheca with operculum; gonangium with acrocyst.

O. lacerata Hincks. Hydrothecae with short stalks; segments of operculum very long and slender: Long Island Sound to Maine, on docks, etc.

5. **Gonothyrea** Allman. Stem erect, irregularly branched, more or less annulated; hydrotheca bell-shaped, with toothed margin; the blastostyle produces fixed, medusiform sporosacs with radial canals and tentacles, which project out of the gonangia but are not free-swimming: several species.

G. loveni Allman (Fig. 186). Stem 10 to 15 mm. high; from the mature gonangium project 3 to 5 sporosacs: on shells, stones, etc., in shallow water from Long Island Sound to Maine; Europe.

G. clarki Torrey. Similar to the above but without radial canals in the sporosacs; hydrotheca deep, with margin having 10 square-topped or bicuspid teeth: Pacific Coast from California to Alaska; often common in shallow water.

Family 4. EUCOPIDAE.

Trophosome: colonial, either branched or simple; hydrotheca bell-shaped and stalked, the margin of the aperture either toothed or not; gonangia large and usually in the axils of the branches. Gonosome: gonangium large, the blastostyle producing free medusae with lithocysts and usually without ocelli, with 4 radial canals, beneath which on the subumbrella are the gonads, there being as many gonads as radial canals: about 34 genera.

Key to the genera of *Eucopidae* here described (hydroid form well known in *Obelia* and *Clytia* alone):

a_1 Manubrium of medusa short; hydroid mostly a branching colony.
b_1 Medusa flat and disc-like; hydroid a branching colony; hydrotheca often without a toothed margin.....1. OBELIA
b_2 Medusa bell-shaped or hemispherical.
c_1 Medusa with no more than 16 marginal tentacles.
d_1 Medusa without cirri at the base of the tentacles; hydroid not or very sparsely branched; hydrotheca with toothed margin.....2. CLYTIA
d_2 Medusa with 4 or more tentacles, each of which has 2 basal cirri. 4. EUCHEILOTA
c_2 Medusa with more than 16 tentacles.
d_1 Oral lobes frilled.....3. TIAROPSIS
d_2 Oral lobes not frilled.....5. OCEANIA
a_2 Manubrium of medusa very long; hydroid mostly unknown.
e_1 Tentacles 4.....6. EUTIMA
e_2 Tentacles of adult numerous.....7. TIMA

1. OBELIA Péron and Lesueur. Hydroid colony usually branched, the stem with annulations at the base of the branches and the hydranths; hydrotheca often with untoothed margin; gonangium with a small terminal aperture, usually surrounded by a collar or neck; medusa more or less disc-shaped, 1 to 6 mm. in diameter, with 12 or more marginal tentacles and 8 lithocysts, often swimming with everted bell: numerous species,

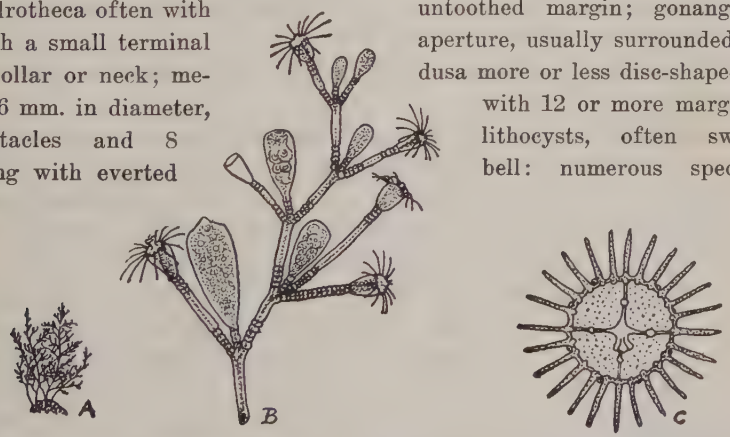

Fig. 187—*Obelia dichotoma* (Mayer). A, entire colony; B, colony enlarged; C, medusa.

the medusae of which can often not be distinguished from one another.

O. commissuralis McCrady. Colony tree-like with long central trunk, 15 to 20 cm. high, sparsely branched, the side branches springing out at right angles; hydrotheca not toothed; gonangia elongate; medusa with 16 or more tentacles: on docks, algae, etc., from South Carolina to Bay of Fundy; common; California.

O. dichotoma (L.) (Fig. 187). Colony rather small with a deep brown stem and a general tree-like appearance; branches zigzag; hydrotheca elongate without toothed margin; gonangia long and conical;

medusa with 16 tentacles at liberation: from South Carolina northwards; common on stones, seaweed, etc.; Pacific coast; Europe.

O. geniculata (L.) (Fig. 188). Colony not more than 30 mm. high and consisting usually of a single zigzag stem bearing alternate hydranths on short annulated stalks; gonangia borne in the angles of these stalks; medusa with 24 tentacles at liberation: on docks, fucus, etc., from Long Island to Labrador; very common; California; cosmopolitan.

Fig. 188
Obelia geniculata (Hargitt).

O. gelatinosa (Pallas). Colony tree-like, profusely branching and very large, being sometimes 25 cm. high or more, with central stems and zigzag branches; hydrothecae small, with toothed margin; gonangia small; medusa with 16 tentacles at time of liberation: on docks, seaweed, etc., in shallow water from New Jersey to Massachusetts Bay; very common; Puget Sound; Europe.

Fig. 189—*Clytia bicophora* (Mayer).

2. **Clytia** Lamouroux. Hydroid colony sparsely branched or not at all, the hydranths being at the end of a usually long, more or less annulated stalk which rises from the hydrorhiza; hydrotheca with toothed margin; gonangia often annulated, on the hydrorhiza or the stem; medusa with 16 tentacles and 16 lithocysts: 8 species.

C. bicophora Agassiz (Fig. 189). Colony about 10 mm. high; medusa 5 mm. in diameter, hemispherical when liberated but later becoming more flattened; gonads brown, manubrium short, with 4 small oral lobes: from South Carolina to Arctic Ocean, on fucus, docks, etc., in shallow water; often common.

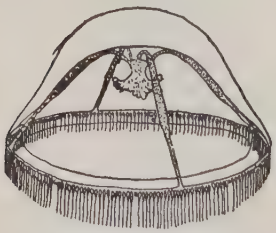

Fig. 190—*Tiaropsis diademata* (Mayer).

3. **Tiaropsis** Agassiz. Hydroid form unknown; medusa hemispherical; marginal tentacles very numerous in adult; manubrium short with frilled mouth opening; 8 lithocysts above each of which is an ocellus: 6 species.

T. diademata Agassiz (Fig. 190). Medusa 15 mm. in diameter, with sloping sides; manubrium with 4 prominent lips: New England coast; often abundant.

4. **Eucheilota** McCrady. Hydroid form unknown; medusa hemispherical; tentacles each with a pair of lateral cirri at its base: 6 species.

E. duodecimalis A. Agassiz (Fig. 191). Tentacles 4, each with a pair of cirri at its base; diameter 2.5 mm.; manubrium very short: Cape Cod to Florida; often common.

5. **Oceania** Péron and Lesueur. Hydroid form mostly unknown; medusa hemispherical with 16 or more tentacles; lithocysts also numerous in adults, 2 being between each two marginal tentacles; gonads

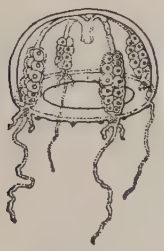

Fig. 191

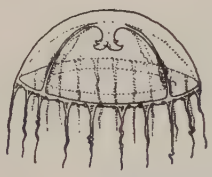

Fig. 192

Fig. 193

Fig. 191—*Eucheilota duodecimalis* (Mayer). Fig. 192—*Oceania languida* (Hargitt). Fig. 193—*Eutima mira* (Hargitt).

colored and borne along the outer half of radial canals: manubrium with 4 everted oral lobes: 6 species.

O. languida A. Agassiz (Fig. 192). Gonads brownish or pink or green; tentacles 20 or more; diameter 20 mm.: from Bay of Fundy to Florida; often common.

6. **Eutima** McCrady. Hydroid form unknown in most species; medusa bell-shaped with 4 or more tentacles and a very long manubrium extending far out of the bell; 8 lithocysts: 12 species.

E. mira McCr. (Fig. 193). Medusa 2 cm. in diameter and half as high, with gonads extending along almost the entire length of radial canals; tentacles 4 in number and very long, the base swollen and colored green: Florida to New England; very common at Woods Hole in August.

Fig. 194

Tima formosa (Hargitt).

7. **Tima** Eschscholtz. Hydroid form minute; medusa hemispherical with a long manubrium sometimes extending out of the bell, at the end of which are 4 frilled projections surrounding the mouth; tentacles numerous; gonads extending the length of the radial canals and the manubrium: 5 species.

T. formosa Agassiz (Fig. 194). Diameter 4 to 8 cm.; gonads and oral lobes milk white: New England coast; often common, especially in the spring.

Family 5. ÆQUOREIDAE.

Trophosome: mostly unknown. Gonosome: medusa often of large size and more or less disc-shaped, with from 8 to 100 radial canals; gonads usually ribbon-like; 8 or more lithocysts; 8 or more marginal tentacles: about 7 genera.

Key to the genera of *Æquoreidae* here described:

a_1 Manubrium short.
b_1 Radial canals 8 to 20 ..... 1. Halopsis
b_2 Radial canals 16 to 100 ..... 2. Æquorea
a_2 Manubrium large and long ..... 3. Zygodactyla

1. Halopsis A. Agassiz. Medusa disc-like in adult and hemispherical in youth; radial canals 12 to 20 in 4 groups; marginal lithocysts, tentacles and cirri numerous; manubrium short with 4 oral lobes: 1 species.

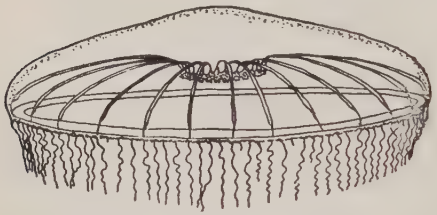

Fig. 195—*Æquorea tenuis* (Mayer).

H. ocellata A. Ag. Diameter 7 cm.: New England coast; rare.

2. Æquorea Péron and Lesueur. Hydroid form minute and mostly unknown; medusa disc-shaped or hemispherical, with a short, wide manubrium and numerous radial canals, lithocysts, and tentacles: 10 species.

A. (*Rhegmatodes* A. Agassiz) **tenuis** A. Ag. (Fig. 195). Radial canals 20 to 40 with an equal number of gonads; tentacles numerous, long and slender, with a spur above the base of each; diameter 3 to 10 cm.: Vineyard and Long Island Sounds; very irregular in its occurrence.

A. albida (A. Ag.) Radial canals and tentacles 80 or more in number; above each tentacle is a spur; diameter 7 cm.: New England coast.

3. Zygodactyla Brandt. Hydroid form unknown; medusa arched and with a large sac-like manubrium with extensive frilled oral lobes extending beyond the velum; subumbrella with rows of warts between the radial canals: 1 species.

Fig. 196—*Zygodactyla grœnlandica* (Mayer).

Z. grœnlandica (Péron and Lesueur) (Fig. 196). The largest American hydromedusan, measuring 12 cm. or more in diameter; radial canals

and tentacles 80 to 100 in number: Greenland to North Carolina, the southern variety being pink.

Family 6. THAUMANTIIDAE.

Trophosome: unknown in most genera. Gonosome: medusa ocellate and without lithocysts, with a short manubrium and usually 4 to 8 radial canals: about 14 genera.

1. Melicertum Oken. Hydroid form minute; medusa bell-shaped; 8 radial canals and numerous long tentacles with ocelli at their base: 4 species.

M. campanula Agassiz. Color of medusa light ochre, tentacles and gonads darker; manubrium short with convoluted lobes; height and diameter 2 cm.: Cape Cod to Greenland, often abundant; Europe.

Fig. 197—*Laodicea calcarata* (Hargitt).

2. Laodicea Lesson (*Lafœa* Lamouroux). Hydroid an unbranched colony with a filiform hydrorhiza; hydrothecae tubular; gonangia oblong, often forming encrusting masses around the stem; medusa hemispherical when young, but flatter as adult, with 4 radial canals and numerous tentacles, with basal cirri and ocelli: 6 species.

L. calcarata A. Agassiz (Fig. 197). Hydroid form usually parasitic on sertularians; medusa transparent with 2 tentacles at birth, but many later, which are quite rigid; manubrium short, with fluted sides; diameter 25 mm.: Massachusetts Bay to Florida.

Order 5. TRACHOMEDUSAE.

Trophosome: wanting in most forms, so far as known; where present, of minute size and allied apparently to the *Tubulariae*. Gonosome: free medusae, usually rather large, more or less bell-shaped, with a velum and 4, 6, or 8 radial canals, along which on the subumbrella are the gonads; manubrium usually long, often extending beyond the velum; tentacles often very long and sometimes springing from the exumbrella; lithocysts with concretions of entodermal origin and either freely projecting or enclosed in pockets; development apparently direct in most cases, without alternation of generations, the animals being essentially open-ocean animals, most of which are not bound to the shores by a hydroid generation, and where the latter is present it is apparently in a degenerate condition: 5 families and 80 species.

Key to the families of *Trachomedusae* here described:

a_1 Radial canals 4 or 6.
b_1 Gonads not plate-like, usually undulating.....1. PETASIDAE
b_2 Gonads plate-like.....3. GERYONIIDAE
a_2 Radial canals 8.....2. AGLAURIDAE

FAMILY 1. PETASIDAE.

Trophosome: minute and apparently rudimentary, so far as known, probably wanting in many cases. Gonosome: medusa with 4 or 6 radial canals; gonads elongate and much folded or sac-like; tentacles either

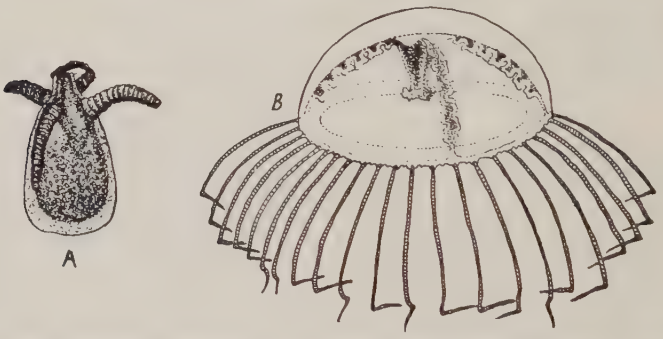

Fig. 198—*Gonionemus murbachi.* A, hydroid (Perkins); B, medusa (Mayer).

with or without a pad-like cluster of modified nettle cells near the distal end for purposes of adhesion; manubrium short: about 14 genera.

1. **GONIONEMUS.*** A. Agassiz. Trophosome: minute, so far as known. Gonosome: medusa with 4 radial canals, along the entire length of which the sinuous gonads extend; adhesive pad near the extremity of each tentacle; numerous lithocysts present: 7 species; cosmopolitan.

G. murbachi Mayer (Fig. 198). Trophosome: solitary hydra-like individuals 1 mm. high with 4 tentacles. Gonosome: medusa 20 mm. in diameter and half as high; marginal tentacles from 16 to 80, long and stiff and green at the base; gonads brown; manubrium short with 4 frilled oral lobes: Vineyard and Long Island Sounds.

G. vertens A. Ag. Similar to the above, but higher than wide: Pacific coast from Washington to Alaska.

2. **MICROHYDRA**† Potts. Trophosome: a minute hydroid without tentacles and solitary, but multiplying by lateral budding. Gonosome: a

* See "The Development of Gonionema murbachii," by H. F. Perkins, Proc. Acad. Nat. Sci., 1902, p. 750.

† See "On the Medusa of Microhydra," etc., by Edward Potts, Quart. Jour. Mic. Sci., Vol. 50, p. 623, 1906. "Microhydra in 1907," Proc. Delaware Co. Inst., Vol. 3, p. 89, 1908.

medusa which buds from the hydroid, bell-shaped, with 4 radial canals and 8 tentacles: 1 species, in fresh water.

M. ryderi Potts (Fig. 199). Hydroid cylindrical, with a crown of nematocysts around the mouth, .5 mm. long, often branched near the base into two equal individuals; medusa .3 mm. high and .4 mm. wide at birth; no sense organs or gonads observed: on stones in rapid streams in Philadelphia; Germany.

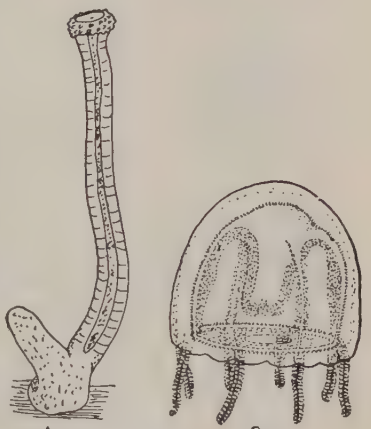

Fig. 199—*Microhydra ryderi* (Potts). A, hydroid; B, medusa.

3. **Craspedacusta** Lankester (*Limnocodium* Allman). Trophosome: minute, without tentacles. Gonosome: disc-like medusa with 4 radial canals; tentacles numerous, of several different lengths; lithocysts numerous; manubrium long: 2 species; distribution world-wide.

C. sowerbi* Lank. (Fig. 200). Diameter about 12 mm.; gonads 4, suspended from the radial canals, greenish in color; oral lobes, large, crenulated, greenish; bell translucent with a faint bluish tint; 4 long, about 28 shorter and 192 shortest tentacles: in a fresh-water aquarium in Washington containing tropical water lilies; also in similar places in London, Munich, and Lyons; probably introduced from South America.

Fig. 200—*Craspedacusta sowerbi* (from Mayer).

Family 2. AGLAURIDAE.

Trophosome: wanting. Gonosome: medusa with 8 radial canals, free lithocysts and gonads in berry-like masses and numerous tentacles: 5 genera.

Key to the genera of *Aglauridae* here described:

a_1 Gonads 8.
  b_1 Gonads borne on manubrium.....1. Aglaura
  b_2 Gonads borne on radial canals.....2. Aglantha
a_2 Gonads 2.....3. Persa

* See "Occurrence of Fresh-water Medusa, Limnocodium, in the United States," by C. W. Hargitt, Biol. Bull., Vol. 14, p. 304, 1908.

1. **Aglaura** Péron and Lesueur. Gonads 8, on manubrium; 8 lithocysts: 1 species.

A. hemistoma Pér. and Les. Medusa cylindrical or octagonal, 4 mm. high, truncated above, transparent; radial canals 8; tentacles numerous, very short; 18 finger-like gonads suspended from the manubrium: cosmopolitan.

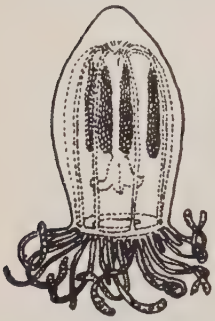

Fig. 201

Aglantha digitalis (Hargitt).

2. **Aglantha** Haeckel. Gonads 8, on subumbrella: 3 species.

A. digitalis (O. F. Müller) (Fig. 201). Medusa elongate, miter-shaped, 30 mm. high and 15 mm. wide, with 8 radial canals, pinkish and transparent; tentacles numerous; gonads elongate and suspended from the upper end of the subumbrella; mouth with 4 everted lips: North Atlantic; often common on the New England coast.

3. **Persa** McCrady. But 2 gonads present, which are thick and elongate and on opposite sides of the umbrella; 8 lithocysts; numerous tentacles: 1 species.

P. incolorata McCr. Bell thimble-shaped and colorless; gonads yellowish; tentacles long and brittle and easily broken off; 3 mm. high and half as wide: coasts of North and South Carolina; rare.

Family 3. GERYONIIDAE.

Trophosome: wanting. Gonosome: medusa hemispherical; manubrium very long; 6 or 8 enclosed lithocysts; radial canals 4 or 6; gonads plate-like: 2 genera.

Liriope Lesson. Manubrium extending far beyond the velum and with a square mouth; 4 radial canals, between each pair of which are 1 to 3 centripetal (*i. e.*, extending from the circular canal upwards) canals, and 4 to 12 tentacles: 20 species.

L. exigua (Quoy and Gaimard) (Fig. 202). Bell hemispherical, 20 mm. wide: Gulf Stream; Mediterranean; occasionally on the New England coast.

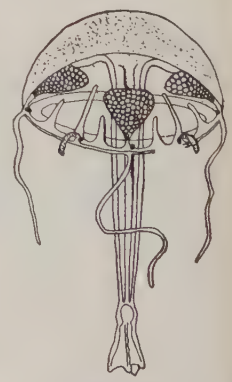

Fig. 202

Liriope exigua (Mayer).

Order 6. NARCOMEDUSAE.

Trophosome: wanting, so far as known, development being direct, the animals living in the open ocean. Gonosome: medusa with lobed

margin; tentacles stiff and extending from the exumbrella; gonads on the subumbrella; gastrovascular cavity a wide central space, either circular in outline or with radial pouches or canals extending outwards; ring canal follows the marginal lobes but is often absent; lithocysts free and often projecting, with entodermal concretions; a thickened ectodermal ring is at the edge of the umbrella with prolongations called peronia extending to the base of the tentacles, and often others also, called otoporpae, extending upwards from the base of the lithocysts: 2 families and 50 species, of which a few are found along our coast.

Family ÆGINIDAE.

Radial pouches of gastrovascular space present: 11 genera.

1. **Cunoctantha** Haeckel. Tentacles, marginal lobes, and radial pouches 8; otoporpae present; the larvae live parasitically in the bell of the mother or some other medusa where they bud off new larvae from a stolon-like prolongation of the apical end of the umbrella: 5 species.

C. octonaria McCrady (Fig. 203). Diameter 7 mm.; manubrium cone-shaped with 4 lips: common at Beaufort, North Carolina, the larvae infesting *Turritopsis nutricula;* cosmopolitan.

Fig. 203—*Cunoctantha octonaria* (Brooks).

2. **Cunina** Eschscholtz. Tentacles and radial canals 9 to 24; the larvae live parasitically in the bell of the mother or some other medusa: 10 species.

C. lativentris Gegenbaur. Medusa flat, transparent, about 16 mm. in diameter; tentacles, marginal lobes, and stomach pouches 10 to 12; lithocysts on each lobe 4: Atlantic Ocean and Mediterranean Sea.

Order 7. SIPHONOPHORA.*

Free-swimming, colonial *Hydromedusae.* The individuals forming a colony are in a high degree polymorphic, there being several orders of individuals all of which are in communication with one another by means of the common gastrovascular space. Each order performs a distinct function in the colony, the division of labor being similar to that which obtains among the various organs of the body of one of the higher animals. Two general types of structure are met with among the *Siphonophora.* In one (Fig. 204) the various individuals bud off from a long axial tube,

* See "The Siphonophorae of the Challenger," by E. Haeckel, Challenger Reports, Vol. 28, 1888.

the upper end of which is expanded to form a float called the pneumatophore which contains air or a gas and serves to keep the colony right side up in the water: in the other type (Fig. 205) no such axial tube is present, the various individuals budding off from the under side of the enormously enlarged float. By far the greater number of siphonophores are of the first type. The individuals budding off from the axis immediately back of the pneumatophore are swimming individuals or nectophores; these are present in pairs, and each has the form of a hydrozoan medusa without the manubrium. Following the nectophores at intervals on the axis are similar groups of individuals, each group consisting usually of (1) the bract, a flat, scale-like protective individual; (2) a club-shaped palp; (3) a nutritive individual or gastrozooid, which is the mouth and stomach of the colony; (4) a long tentacle with nematocysts; (5) reproductive individuals or gonozooids, which are usually unisexual. A colony of this kind swims about slowly in the sea and may be several feet in length and contain thousands of individuals. A modification of this type is seen in the deep-sea siphonophores of the genera *Stephalia* and *Rhodalia,* in which the pneumatophore is very large and the axis short and thick. In *Stephalia* a mouth is present at the terminal end of the axis, which forms the chief gastrozooid: the axis is thus in this case directly comparable with the manubrium of a medusa, of which the pneumatophore would be the bell. In *Rhodalia* the axis has lost its character of a gastrozooid, not having a mouth at the lower end. These animals are probably primitive siphonophores and seem to indicate the derivation of the group from a medusan instead of from a mixed hydroid and medusan stock. They also form a connecting link between the two general types of *Siphonophora,* those with an axial tube and those which have none.

Fig. 204—Diagram of a siphonophore (McMurrich). 1, pneumatophore; 2, nectophore; 3, bract; 4, gonozooid; 5, gastrozooid; 6, club; 7, tentacle.

Fig. 205

Diagram of a *Porpita* (Delage et Hérouard).

Siphonophores are essentially pelagic animals, although some forms are found in deep water. They belong to the open ocean, especially of the warmer parts of the world, and are among the most beautiful and conspicuous animals found there. The order contains about 250 species, grouped in 4 suborders.

Key to the suborders of *Siphonophora:*

a_1 Pneumatophore present.
  b_1 Pneumatophore very large; nectophores absent.
    c_1 Pneumatophore a disc, with a large central gastrozooid....1. DISCONECTAE
    c_2 Pneumatophore more or less cylindrical, without a large central gastrozooid.....2. CYSTONECTAE
  b_2 Pneumatophore usually small; nectophores present; colony usually elongate .....3. PHYSONECTAE
a_2 Pneumatophore absent; nectophores very large; colony swimming rapidly. 4. CALYCONECTAE

SUBORDER 1. DISCONECTAE.

Siphonophores with a very large disc-like pneumatophore and without swimming individuals (Fig. 205). The pneumatophore has a complex structure; it contains a number of air chambers and beneath its center is a single large trunk which bears the principal mouth and stomach of the colony. Surrounding the trunk are small reproductive individuals which bear the gonads, and surrounding them near the rim of the disc are long dactylozooids or tentacles armed with nemotocysts. The whole colony bears a striking resemblance to a medusa: 36 species, grouped in 2 families.

FAMILY VELELLIDAE.*

Pneumatophore a circular or elliptical disc without marginal indentations: about 30 species.

1. VELELLA Bosc. Disc elliptical and very flat and with an elevated ridge passing diagonally across it, which acts as a sail as the animal floats on the surface of the water: 13 species.

V. mutica Bosc (Fig. 206). Length of disc 4 cm., breadth 2 cm.: along the South Atlantic coast, occasionally off New England.

Fig. 206—*Velella mutica* (from Lankester).

2. PORPITA Lamarck. Disc circular, and without the sail: 8 species.

P. linnæana Lesson (Fig. 205). Diameter of disc 3 to 5 cm.: along the South Atlantic coast, occasionally off New England.

SUBORDER 2. CYSTONECTAE.

Siphonophores with a very large pneumatophore from the under side of which project nutritive individuals, no large central trunk and no swimming individuals being present. The colony floats on the surface of the water, often carried by currents and the wind long distances, and can sink beneath the surface by compressing the pneumatophore

* See "The Porpitidae and Velellidae," by A. Agassiz, Mem. Mus. Comp. Zool., Vol. 8, 1883.

and driving out the air or gas through a pore in its upper side. In order to rise to the surface again it fills the pneumatophore with a self-generated gas. The suborder contains 30 species grouped in 5 families.

FAMILY PHYSALIIDAE.

With the above-described characters: 4 genera and 10 species.

Fig. 207
Physalia pelagica (Lankester).

PHYSALIA Lamarck. Pneumatophore with a dorsal crest with transverse septa: 4 species.

P. pelagica Bosc. Portuguese man-of-war (Fig. 207). Pneumatophore up to 12 cm. long, pear-shaped with iridescent colors; tentacles long, sometimes stretching 10 or 15 meters, and with powerful stinging organs: in the Gulf Stream from Florida to Vineyard Sound and occasionally to the Bay of Fundy; often common.

SUBORDER 3. PHYSONECTAE.

Siphonophores with a pneumatophore with a long trunk or axis from which bud off nectophores and successive similar groups of individuals, each group containing usually a bract, a gastrozooid, a palp, a tentacle, and a gonozooid: 9 families and about 75 species.

FAMILY AGALMIDAE.

Two longitudinal rows of alternating nectophores; trunk long, bearing numerous groups of individuals: 30 species.

CUPULITA Quoy and Gaimard (*Nanomia* A. Agassiz). Four to 6 nectophores in each row; individual groups not all of the same importance, there being secondary groups lacking the gastrozooids between the principal groups: several species.

C. cara (A. Ag.). Length of colony about 11 cm.: Newport and Massachusetts Bay.

SUBORDER 4. CALYCONECTAE.

Siphonophores with very large swimming individuals (nectophores) and without pneumatophore or palps, the individual groups consisting each of a nutritive and one or more reproductive individuals, a covering bract, and a short tentacle. The colony swims rapidly, in contrast to most siphonophores, being partly sustained by a drop of colored oil present in each nectophore: 5 families and 95 species.

FAMILY DIPHYIDAE.

Two nectophores present: 10 genera and about 35 species.

DIPHYES Cuvier. Nectophores conical and very large; the remainder of colony can be retracted into a groove in the nectophores and is constantly being shortened by the breaking off of the terminal and oldest groups of individuals, each group (which is called an *Eudoxia*) thus separated leading an independent life and becoming sexually mature: 6 species.

D. bipartita Costa (Fig. 208). Total length 30 mm.; length of the nectophores 10 mm.; body transparent: tropical and subtropical Atlantic; Mediterranean; occasionally on New England coast; often very common.

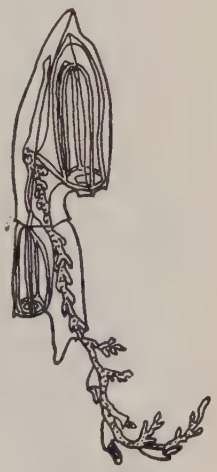

Fig. 208
Diphyes bipartita (Hargitt).

CLASS 2. **SCYPHOZOA.** (SCYPHOMEDUSAE.)

These animals have usually an alternation of generations, in a few (*Pelagia*), however, the medusoid generation and in others (*Lucernaria*) the hydroid alone being present. The medusoid plays a much more conspicuous part than the hydroid. The latter is a small, usually non-colonial animal called the scyphistoma, which is less than a centimeter in height and resembles the fresh-water *Hydra* in appearance (Fig. 217, A). It differs from *Hydra,* however, in that the aboral end is fixed to the bottom in a cup formed of the perisarc, in the possession of four longitudinal folds of the entoderm called mesenteries which project into the gastrovascular space and of an ectodermal gullet. The scyphistoma is an asexual animal and reproduces by budding exclusively. New scyphistomas may be produced by a process of lateral budding from stolons sent off from the foot. The medusoid generation is produced by a process of terminal budding called strobilation (Fig. 217, B). The scyphistoma grows in height and a series of constrictions appear which divide it into a number of discs. Each disc is called an ephyra (Fig. 217, C) and is a young medusa or jellyfish, which on becoming free grows in time to be a sexual animal.

The medusa which is thus produced is often a large animal; *Cyanea* may be two meters and more in diameter with tentacles thirty-five meters or more long. It is called acraspedote because the velum, which is so characteristic of the craspedote *Hydromedusae,* is wanting or rudimentary. The periphery of the bell is lobed or scalloped and may or may not have tentacles. The manubrium is sometimes very long and

large and extensively branched and in the *Rhizostomata* the mouth is closed by the coalescence of its sides, small pores remaining through which nutriment is taken in. The gastrovascular space is complex in form and usually consists of four radial pouches forming a large space in the center of the animal and additional radial canals which often branch and may be joined at their outer ends by a circular canal.

The gonads are four in number and often brightly colored; they are specialized portions of the entoderm and appear in the interradii of the gastrovascular space. In many species four large pockets, called the subgenital pockets (Fig. 216, S) and probably respiratory in function, are present in the subumbrella directly beneath the four gonads. Beside each gonad are usually a number of cylindrical mesenterial filaments, armed with nettle organs.

The finer structure of the *Scyphozoa* is essentially like that of the *Hydrozoa*. The mesoglea is different, however, in that it is much firmer and usually cellular. The sense organs are also different, being perhaps modified tentacles, and are called tentaculocysts or rhopalia.

The *Scyphozoa* are all marine and among the most familiar animals along our shores. The class contains 5 orders and about 180 species.

Key to the orders of *Scyphozoa:*

a_1 Body stalked and sessile, there being no medusa stage....1. STAUROMEDUSAE
a_2 Free-swimming medusae present.
b_1 Medusa with distinct constriction about its middle.....2. CORONATAE
b_2 No such constriction present.
c_1 Tentacles present either on the margin or the subumbrella.
d_1 Medusa cuboidal in shape with 4 long marginal tentacles or groups of them.....3. CUBOMEDUSAE
d_2 Medusa with 8 or more tentacles on margin or subumbrella. 4. SEMÆOSTOMEAE
c_2 No tentacles on margin or subumbrella.....5. RHIZOSTOMAE

ORDER 1. STAUROMEDUSAE.

Body conical in shape with aboral surface usually drawn out to form a stalk by which it is temporarily attached, representing a sexual scyphistoma; margin with 8 prominent lobes, each with a cluster of short knobbed tentacles; without sensory organs but often with marginal adhesive pads (marginal anchors) in the angles between the lobes: 25 species and 2 families, the animals usually attached to seaweed in shallow water.

FAMILY LUCERNARIIDAE.*

Margin with 8 lobes, each with numerous knobbed tentacles; animal attaches itself temporarily to algae, along which it crawls: 5 genera.

* See "Lucernariae and Their Allies," etc., by H. J. Clark, Smithsonian Contrib. to Knowledge, Vol. 23, 1878.

Key to the genera of *Lucernariidae* here described:

a_1 Adhesive pads absent.....1. LUCERNARIA
a_2 Adhesive pads present.
b_1 Stalk quadrate.....2. HALICLYSTUS
b_2 Stalk cylindrical.....3. HALIMOCYATHUS

1. **LUCERNARIA** O. F. Müller. Marginal adhesive pads absent; stalk cylindrical: 8 species, 1 American.

L. quadricornis Müll. Height 7 cm.; diameter 5 cm.; color green, gray, or reddish; tentacles on each lobe 100 or more: Cape Cod to Greenland; Europe.

2. **HALICLYSTUS** Clark. Eight marginal adhesive pads between the lobes; stalk quadrate: 6 species, 2 American.

H. auricula Clark (Fig. 209). Height and diameter 3 cm.; color variable; tentacles on each lobe 100 or more: Cape Cod to Greenland; Europe; Alaska.

H. salpinx Clark. Height 20 mm.; diameter 25 mm.; tentacles slender, about 70 on each lobe; marginal pads very large and as long as the tentacles: Cape Cod to Greenland; Adriatic Sea.

Fig. 209—*Haliclystus auricula* (Mayer).

3. **HALIMOCYATHUS** Clark. Marginal adhesive pads present; 4 gastrogenital pockets present in subumbrella wall of the gastrovascular pouches; stalk cylindrical: 2 species.

H. lagena (Haeckel). Height 3 cm.; diameter 7 mm.; tentacles on each lobe 70: Cape Cod to Greenland; rare; Europe.

ORDER 2. CORONATAE.

Medusa with a constriction about its middle; margin in most cases with 16 lobes, long tentacles and rhopalia: 5 families and 27 species, which are usually found in the open ocean.

FAMILY 1. PERIPHYLLIDAE.

Marginal lobes 16; tentacles 4 or more; rhopalia 4: 4 genera and 8 species.

PERIPHYLLA Steenstrup. Twelve tentacles; body conical; 4 deep subgenital pockets (funnels); gonads horseshoe-shaped: 3 species.

P. hyacinthina Steen. (Fig. 210). Medusa about 8 cm. high and 4 cm. wide; color reddish: Greenland; Gulf Stream; cosmopolitan.

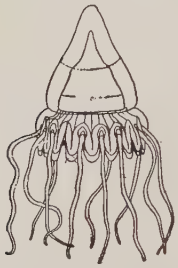

Fig. 210

Fig. 211

Fig. 210—*Periphylla hyacinthina* (Mayer). Fig. 211—*Nausithoë punctata* (Mayer).

Family 2. EPHYROPSIDAE.

Usually 16 marginal lobes; 9 rhopalia and 8 or more tentacles: 3 genera and 11 species.

1. Nausithoë Kölliker. Gonads 8; tentacles 8; marginal lobes 16; ectoderm of bell with clusters of small crystals: 6 species.

N. punctata Köll. (Fig. 211). Medusa 10 mm. broad and 4 mm. high; marginal tentacles stiff: cosmopolitan; Gulf Stream; common.

2. Linuche Eschscholtz. Similar to *Nausithoë* but with sac-like gastric pouches: 2 species.

L. unguiculata Eschs. (Fig. 212). Medusa cylindrical or thimble-shaped, 13 mm. high and 16 mm. wide: Gulf stream; often in swarms.

Fig. 212—*Linuche unguiculata* (Mayer).

Order 3. CUBOMEDUSAE.

Body more or less cuboidal in form, with a single interradial tentacle or a group of tentacles at each of the 4 corners, the bases of which are in most forms expanded to form prominent flattened structures called pedalia; rhopalia 4, between the tentacles; 4 wide gastric canals in which are the plate-like gonads; false velum (velarium) present, which together with their energetic swimming movements gives the animals the appearance of craspedote medusae: 1 family and about 16 species.

FAMILY CHARYBDEIDAE.

With the characters of the order: 6 genera.

1. **TAMOYA** F. Müller. Four tentacles, with prominent pedalia; 4 clusters of gastric cirri: 1 species.

T. haplonema F. Mül. (Fig. 213). Medusa 9 cm. high and 5 cm. in diameter; exumbrella covered with wart-like clusters of nematocysts: Long Island Sound to West Indies.

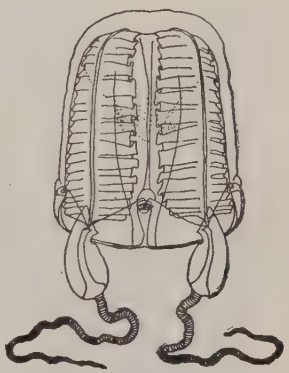

Fig. 213—*Tamoya haplonema* (Mayer).

2. **CHIROPSALMUS** Agassiz. Four groups of about 8 tentacles each, each group extending from the fingers of a palmate pedalium; finger-like sacs extending into the cavity of the bell from near the base of the manubrium: 4 species.

C. quadrumanus Ag. Medusa 10 cm. high and 14 cm. in diameter: North Carolina and southwards, often common in shallow water.

ORDER 4. **SEMÆOSTOMEAE.**

Mouth quadrate, with 4 long, oral lobes, often folded and frilled; marginal tentacles hollow, often very long; rhopalia marginal: 3 families.

Key to the families of *Semæostomeae:*

a_1 Very long marginal tentacles.....1. PELAGIIDAE
a_2 No long marginal tentacles.
b_1 Long tentacles on subumbrella; no marginals.....2. CYANEIDAE
b_2 Short marginal tentacles.....3. ULMARIDAE

FAMILY 1. PELAGIIDAE.

Fig. 214—*Pelagia cyanella* (Mayer).

Large, brightly colored medusae, disc-like or hemispherical in form, with wide, simple, radial gastral pouches and no ring canal, and very long oral lobes and marginal tentacles: 5 genera and 18 species.

1. **PELAGIA** Péron and Lesueur. Eight tentacles and 8 rhopalia; 16 marginal lobes; exumbrella covered with warts of nettle cells; development direct, no hydroid stage being present: 7 species.

P. cyanella Pér. and Les. (Fig. 214). Diameter 5 cm.; height 4 cm.: coast of Florida and the Carolinas, occasionally appearing as far north as New England.

2. Dactylometra Agassiz. Forty marginal tentacles; 8 rhopalia; 48 marginal lobes: 5 species.

D. quinquecirrha (Desor). Diameter up to 25 cm.: Long Island and Vineyard Sounds to the tropics.

Family 2. CYANEIDAE.

Large disc-shaped medusae; radial pouches of the gastrovascular cavity very wide and ramifying at their distal ends; no ring canal and no subgenital pouches: 4 genera, containing the largest medusae; 6 species.

Fig. 215—*Cyanea capillata var. artica* (Mayer), showing the subumbrella with the tentacles and the oral lobes partly removed. 1, oral lobe; 2, gonad; 3, tentacles.

Cyanea Péron and Lesueur. Eight groups of very long tentacles which extend from the subumbrella; oral lobes very long, wide, and voluminous, between which and the tentacles are the 4 large bunches of gonads which have evaginated from the gastrovascular cavity; 8 rhopalia in as many marginal indentations: 2 species.

C. capillata (L.) var. **arctica** Pér. and Les. (Fig. 215). Disc usually 10 to 50 cm. in diameter, but specimens 2 m. in diameter have been seen with tentacles 40 m. long; color variable, usually purplish red or brown; the largest jellyfish: common from North Carolina to Greenland; a light-brown variety called *C. fulva* Agassiz occurs in Long Island Sound, and a bluish-white variety called *C. versicolor* Ag. off the Carolina coast.

Family 3. ULMARIDAE.

Radial canals narrow and branching, forming a complex system with a circular canal joining the distal ends: 10 genera and 17 species.

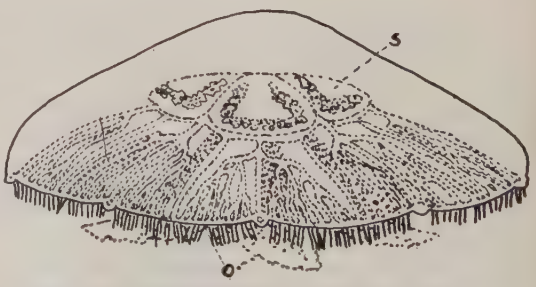

Fig. 216—*Aurelia aurita var. flavidula* (Mayer). s, subgenital pockets; o, oral lobes.

Aurelia Péron and Lesueur. Oral lobes long and rather narrow; marginal tentacles minute; body flat and disc-like; 4 large subgenital pockets; 8 rhopalia in as many marginal indentations: 5 species.

A. aurita (L.) var. flavidula Pér. and Les. (Figs. 216 and 217). Disc may be 30 cm. or more in diameter; color white or bluish with pink gonads: very common along the entire Atlantic coast, breeding throughout the summer, the scyphistoma stage lasting throughout the winter.

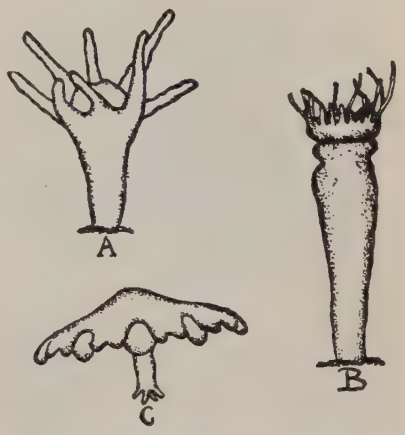

Fig. 217—Young stages of *Aurelia aurita var. flavidula* (Agassiz). A, a scyphistoma; B, a young strobilla; C, an ephyra.

Order 5. RHIZOSTOMAE.

Marginal tentacles absent; 8 oral lobes very large and much branched extend from the center of the subumbrella with sucking pores along their edges which take the place of a mouth, the mouth being usually obliterated; oral tentacles border the pores: 63 species.

1. Stomolophus Agassiz. Body hemispherical; the fused oral lobes form a thick cylinder at the bottom of which are 8 pairs of frilled lobes and a central mouth opening; 8 rhopalia: 1 species.

Fig. 218—*Stomolophus meleagris* (Mayer).

S. meleagris Ag. (Fig. 218). Diameter 18 cm.; color of exumbrella brown: from Florida to North Carolina and occasionally to the coast of New England; often common.

2. Rhopilema Haeckel. Body hemispherical; 8 separated, 3-winged oral lobes from which numerous club-shaped filaments hang: 3 species, one of which, *R. esculenta,* is the edible jellyfish of China and Japan.

R. verrilli (Fewkes). Diameter 35 cm.; 8 rhopalia; color yellowish: Long Island Sound to North Carolina and southwards.

Class 3. **ANTHOZOA.** (Actinozoa.)

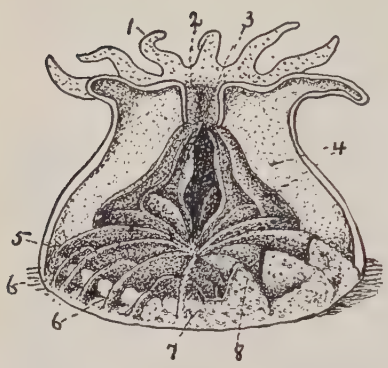

Fig. 219—Diagram of a longitudinal section of a coral animal (Boas). 1, tentacle; 2, mouth; 3, gullet; 4, mesentery; 5, base of a mesentery which has been cut away; 6, septum of the calcareous skeleton covered by a fold of the foot; 7, theca; 8, septum.

Corals, sea anemones, etc. Cœlenterates in which the polyp form alone is present, no medusa generation appearing. The body (Fig. 219) is usually cylindrical in form and is attached either permanently or temporarily at one end, which, in the sea anemones, is called the foot or pedal disc. The other and flattened end is the oral disc; in its center is the mouth surrounded by hollow tentacles, which may number from six to several hundred. The mouth is not round, but an elongated slit, at one or both ends of which is a prominent, ciliated groove called the siphonoglyph, through which the genital products may reach the outside (Fig. 220). The mouth does not lead directly into the gastrovascular space, but into a tube lined with ectoderm called the gullet which opens into the gastrovascular cavity below. This cavity is divided into a number of communicating chambers by six or more wide longitudinal ridges called the mesenteries, which spring from the body wall and project towards the center of the cavity; in the upper portion of the body, certain of these mesenteries join the body wall with the wall of the gullet (Fig. 220), thus dividing this part of the gastrovascular space into small chambers which are continued above in the hollow tentacles, while in the lower portion of the gastrovascular space the edges of the mesenteries are free.

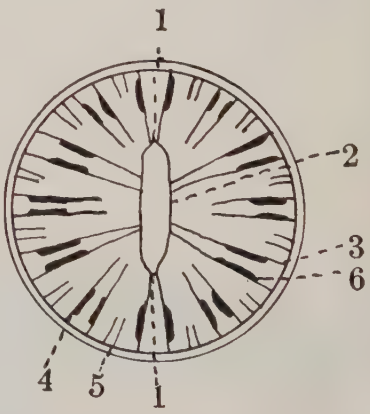

Fig. 220—Diagram of a cross section of an anthozoan through the gullet (Weysse). 1, siphonoglyph; 2, gullet; 3, primary mesenteries; 4, secondary mesenteries; 5, tertiary mesenteries; 6, longitudinal muscle.

Along the free edge of each mesentery is a convoluted thickening, the mesenterial filament, which is of great importance inasmuch as it contains

the gonads, and also nematocysts; at its lower end also, in many species, are long threads called acontia charged with nematocysts which can be protruded from the mouth and also, in some cases, through pores (cinclides) in the body wall. The mesenteries bear the retractor muscles, each of which appears as a prominent ridge on one side of it. At the upper end of the body is usually a strong sphincter muscle which draws this end together and closes the mouth. The body wall consists of the two main cell layers and the mesoglea, which contains nuclei. The mesenteries are composed of mesoglea and entoderm; the important retractor muscles and the gonads being thus of entodermal origin, the latter migrating later into the mesoglea of the mesenteries where they are found.

Very characteristic is the skeleton, which most *Anthozoa* possess. This is composed either of calcium carbonate or a horn-like substance called ceratine, both of which are secreted by the ectoderm and serve to elevate the colony in the water, bringing it into a favorable position for maintaining itself.

The *Anthozoa* are in most cases unisexual. The ova and sperm are thrown into the gastrovascular space, where in many cases a portion of the development may be carried on. In some sea anemones, the young are carried awhile in pits on the side of the body. After a short free life, the young animal settles to the bottom, and in most cases becoming fixed, develops into the adult animal. Asexual reproduction by budding is very general and leads to the formation of the colonies which are so characteristic of the group. All of the *Anthozoa* are marine animals and are especially numerous in the warmer parts of the world. Corals are of importance to man because of the coral reefs, banks, and islands they help to form. The only species which have commercial importance are the red corals of the Mediterranean and Japan which are used in the manufacture of jewelry. The name of the class originated with Ehrenberg, who in 1831 divided the polyps as then known into two groups, the *Anthozoa* or flower animals and the *Bryozoa* or moss animals. The class contains over 2,000 living and many fossil species, which are grouped in two orders.

Key to the orders of *Anthozoa:*

a_1 Eight pinnate tentacles present.....1. ALCYONARIA
a_2 Tentacles simple and usually numerous.....2. ZOANTHARIA

ORDER 1. ALCYONARIA.*

Colonial *Anthozoa* with 8 pinnate tentacles and 8 mesenteries (Fig. 222, B). A siphonoglyph is present on but one side of the polyp, or not at all. The retractor muscles are all on the same side of the mesen-

* See "Alcyonaria of Porto Rico," by C. W. Hargitt and C. R. Rogers, Bull. U. S. Fish. Com., Vol. 20, p. 267, 1900.

teries, that which looks towards the siphonoglyph. The skeleton consists of calcium carbonate or ceratine spicules imbedded in the mesoglea, but formed by cells of ectodermic origin, which may be fused together in the center of the colony so as to form a compact axis: in a few genera a skeleton is lacking. The mesoglea, stiffened thus by the spicules, together with the outer ectoderm, is called the cœnenchym. The polyps are seated in depressions in the cœnenchym, into which they can usually retract, and are in communication with one another by means of entodermal canals (Fig. 222, B). The *Alcyonaria* are often brightly colored and phosphorescent and are among the most conspicuous objects in the tropical seas. The order contains about 33 families and over 600 living species, grouped in 5 suborders.

Key to the suborders of *Alcyonaria* here described:

a_1 Colony fixed and stationary.
  b_1 Polyps rise from a stolon.....1. STOLONIFERA
  b_2 Colony erect.
    c_1 Central skeletal axis absent.....2. ALCYONACEA
    c_2 Central skeletal axis present.....3. GORGONACEA
a_2 Colony not fixed or stationary.....4. PENNATULACEA

SUBORDER 1. STOLONIFERA.

Colony consists of independent polyps which rise from a membranous or ribbon-like stolon; they are not continuously joined but may be united by transverse tubes or plates: 3 families.

FAMILY CORNULARIIDAE.

Polyps not joined together except by the creeping stolon from which they spring; spicules usually absent: about 15 genera.

CORNULARIELLA Verrill. Upper portion of polyp retractile into the rigid lower portion; spicules present: 1 species.

C. modesta Ver. Polyps 6 to 18 mm. high and 3 mm. in diameter; color of stolons and lower part of polyps yellow or brown: Casco Bay to Gulf of St. Lawrence, from 30 fathoms to deep water.

SUBORDER 2. ALCYONACEA.

Colony usually branching, without central axis; cœnenchym with spicules and usually fleshy: about 10 families and over 100 species.

FAMILY 1. ALCYONIIDAE.

Colony simple or branching and more or less massive; polyps elongate and joined by entodermal canals; cœnenchym with numerous spicules: about 12 genera.

ALCYONIUM L. Colony composed of short, thick lobes and soft or leathery; polyps long and, with the exception of the outer end with the

tentacles, entirely buried in the mass of the cœnenchym which forms the bulk of the colony: numerous species.

A. carneum Agassiz. Colony yellowish or reddish in color, lobed or arborescent and 4 to 10 cm. high: from Long Island Sound to Gulf of St. Lawrence, from low water to 80 fathoms.

Family 2. NEPHTHYIDAE.

Colony more or less dendritic, consisting of a sterile trunk and branches bearing polyps; consistency soft and leathery; polyps not retractile, with tentacles folded over oral disc when at rest: 10 genera.

Spongodes Lesson. Colony massive or dendritic; spicula in periphery of polyps so numerous that neither the polyp nor their tentacles are retractile; polyp surrounded by giant spicules which project from its base beyond the tentacles: 40 species.

S. portoricensis Hargitt. Colony about 45 mm. high, whitish in color, densely spinose: near Porto Rico, in 75 fathoms.

Suborder 3. GORGONACEA.

Sea fans, sea whips, red coral, etc. Colony usually branching extensively and with a central skeletal axis, composed of compacted spicules, which is either calcareous, horn-like, or composed of calcareous alternating with horn-like segments; a rind of cœnenchym containing spicules covers this axis, in which the polyps are imbedded, being joined together by entodermal canals: about 11 families and over 250 species.

Family 1. CORALLIIDAE.

Colony erect, branching, with a dense, calcareous axis of fused spicules surrounded by canaliferous cœnenchym bearing spicules: about 3 genera.

Corallium Lamarck. Red coral. Polyps white in color and retractile; spicules and axis red; axis thick and longitudinally ridged by entodermal canals, very hard, forming the red coral of commerce: about a dozen species, in the Mediterranean, eastern Atlantic, and off the coast of Japan.

C. nobile (Pallas) (*C. rubrum* Lam.). Colony up to 30 cm. high: in the central and western Mediterranean, being fished principally off the coast of Africa and Italy.

Family 2. GORGONIIDAE.

Colony erect and branched, often in one plane; axis horn-like, occasionally horn-like and calcareous; polyps occur in rows and on two sides only of the stem and branches: 12 genera.

Gorgonia L. Colony arborescent, often fan-shaped, the branches being in the same plane and often anastomosing so as to form a network; polyps retractile: numerous species.

Fig. 221
Gorgonia flabellum (Hargitt).

G. flabellum L. Sea fan (Fig. 221). Colony a network with meshes 2 to 6 mm. wide, yellowish or reddish in color and up to 50 cm. high and wide: South Atlantic and West Indies, in shallow water.

G. acerosa Pallas. Colony dendritic, with long, slender branches, the smaller branches being arranged pinnately, up to 80 cm. high, straw-colored: West Indies, in shallow water.

Family 3. PLEXAURIDAE.

Colony branched and erect, with the polyps scattered over entire surface; axis horn-like or horn-like and calcareous; cœnenchym thick; polyps rather large and projecting: 10 genera.

1. **Eunicea** Lamouroux (Fig. 222). Colony arborescent; trunks cylindrical; polyp edges bilobed or crenate; axis horn-like: numerous species.

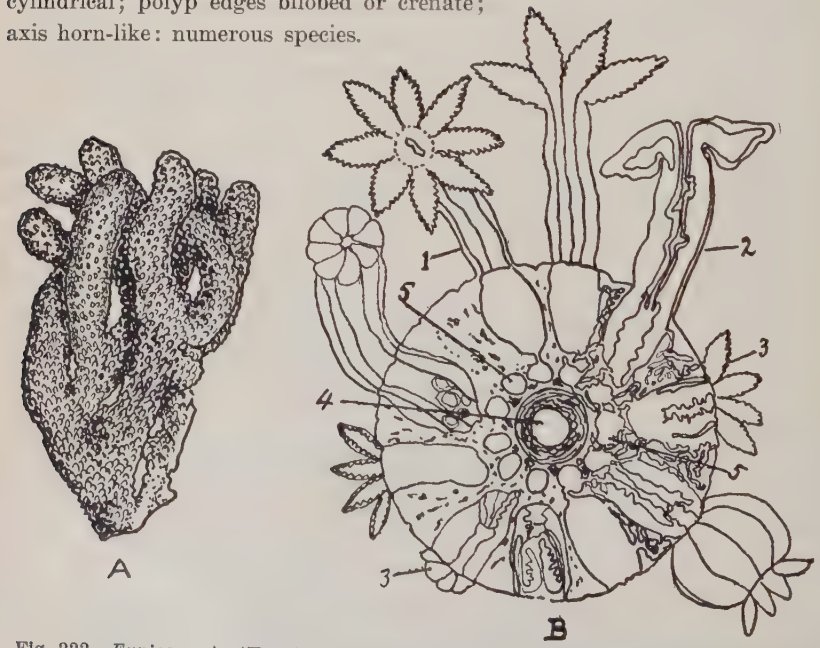

Fig. 222—*Eunicea*. A, (Hargitt) entire colony; B, (Chester) cross section showing polyps. 1, expanded polyp; 2, longitudinal section of polyp; 3, contracted polyp; 4, central axis; 5, entodermal canal.

E. crassa Edwards and Haime. Colony up to 50 cm. high and half as broad; diameter of trunks 8 to 15 cm.; cœnenchym thick, corky: West Indies.

2. **Plexaurella** Kölliker. Colony arborescent; trunks cylindrical; axis horn-like and calcareous; cup edges smooth; cœnenchym usually very thick.

P. dichotoma Dana. Stem 12 to 20 mm. thick; branches smooth, club-shaped; color brownish: West Indies; very common.

Suborder 4. PENNATULACEA.*

Sea pens and sea feathers. Colony not fixed, but capable of independent movement and consisting of two parts, a stalk which is imbedded in sand or mud, and an upper part called the rachis, which bears the polyps and may have the form of a feather, a rod, a broad plate; a central calcareous or horn-like axis usually present; outer layer of mesoglea permeated with spicules forming a crust; polyps large and in communication with one another by entodermic canals and dimorphic, the autozooids being of ordinary structure, the smaller siphonozooids having no tentacles or gonads and reduced mesenteries and serving for the inflow and outflow of water through the entodermal canals: 15 families and over 200 species.

Fig. 223

Pennatula aculeata (Verrill).

Family 1. PENNATULIDAE.

Sea feathers. Rachis elongate with paired lateral branches or pinnulae; siphonozooids confined to lower side of rachis: about 4 genera.

Pennatula Lamarck. Pinnulae long, from 20 to 50 in number on each side, bearing the autozooids on their upper margin: several species.

P. aculeata Danielsen (Fig. 223). Length 10 cm.; rachis with numerous spines among the siphonozooids; color deep red, stalk rose-colored, becoming whitish at the base: Gulf of St. Lawrence to Carolina, in 100 to 500 fathoms; common; Europe.

P. grandis (Ellis) (*P. borealis* Sars). Length up to 50 cm.; color orange; breadth 14 cm.: Newfoundland to Nantucket, in 100 to 600 fathoms.

* See "Die Pennatuliden," by A. Kölliker, Frankfort, 1870.

Family 2. FUNICULINIDAE.

Sea pens. Stalk short and thicker than the quadrangular rachis which is long and slender and bears the autozooids in oblique rows; autozooids retractile; siphonozooids confined to lower side of rachis: 1 genus.

Funiculina Lamarck. With the characters of the family: 2 species.

F. armata Verrill. Length up to 60 cm.; autozooids deep purple; rachis yellowish below and brownish above: Newfoundland to Nantucket, in 100 to 400 fathoms.

Fig. 224
Renilla reniformis (Cambridge Natural History).

Family 3. RENILLIDAE.

Rachis broad and circular or reniform, with the polyps confined to the upper surface; no axial skeleton: 1 genus.

Renilla Lamarck. With the characters of the family: 10 species.

R. reniformis (Pallas) (Fig. 224). Upper part pink or violet in color, polyps white; 7 cm. long: on the Carolina coast, in shallow water; West Indies.

Order 2. ZOANTHARIA.

Stony corals and sea anemones. *Anthozoa,* often of large size, most of which secrete a stony or horn-like skeleton. The tentacles are usually simple (in the Australian sea anemone, *Actinodendron,* branched) and may number from six to several hundred.

The mesenteries (Fig. 220) are usually numerous, consisting of six primary pairs (protocnemes) which alone are present in the most primitive forms, and numerous secondary mesenteries (metacnemes) which are usually unilateral, that is, in pairs, both members of which are on the same side of the gullet, and arise in series, the younger and smaller pairs appearing between the older and larger ones. The gullet is joined with the body wall by all of the protocnemes (except in *Edwardsia*) and usually by certain of the metacnemes, the two pairs of protocnemes which join the siphonoglyphs with the body wall being called the directives. The order contains 1,500 species, grouped in three suborders.

Key to the suborders of *Zoantharia:*

a_1 Skeleton present; animals mostly colonial.
  b_1 Skeleton horn-like.....1. Antipatharia
  b_2 Skeleton calcareous.....3. Madreporaria
a_2 No skeleton; animals mostly solitary.....2. Actiniaria

Suborder 1. ANTIPATHARIA.

Black corals. Colonial *Zoantharia* having the appearance of alcyonarians, with a black, horn-like central axis and a thin cœnenchym in which are no spicules; polyps usually with 6 tentacles and 6 mesenteries: 3 families with about 100 species, most of which live in the deep sea.

Family ANTIPATHIDAE.

Colonies composed of long, slender stalks and branches; polyps with 6 tentacles, 6 primary mesenteries, and with or without 4 or 6 secondary mesenteries; axis beset with spines and with a central canal: about 30 species.

1. Antipathes Pallas. Colony branching; axis with long, numerous spines: about 15 species.

A. larix Esper. Colony up to 1 m. high and composed of a few long main stalks each bearing 6 longitudinal rows of parallel branches from 3 to 10 cm. long: West Indies; Mediterranean.

2. Cirripathes Blainville. Colony not branched but consisting of a simple long and flexible and often spiral stalk: several species.

C. spiralis (L.). Colony a meter or more long and spiral: West Indies; Mediterranean; Indian Ocean.

Suborder 2. ACTINIARIA.*

Sea anemones. Skeleton not present; animals usually solitary; often very brightly colored and of large size, occurring in all parts of the world, in all depths of water; the animals usually attach themselves temporarily to some more or less stationary object by the broad sucker-like foot, but can usually move about slowly; some live in the sand and a few are free-swimming: about 400 species, grouped in 4 divisions.

Key to the divisions of *Actiniaria:*

a_1 Eight longitudinal ridges on the outer surface of the body....1. Edwardsiae
a_2 At least 12 ridges or none at all.
b_1 But 2 rows of tentacles, an outer marginal and an inner..2. Ceriantheae
b_2 Tentacles not in two rows.
c_1 Animals colonial.....3. Zoantheae
c_2 Animals solitary.....4. Hexactiniae

Division 1. EDWARDSIAE.

Solitary sea anemones, small and slender, usually imbedded in the sand, the foot being pointed for burrowing; with 14 to 48 tentacles and

* "Report of the Actinia," etc., by J. P. McMurrich, Proc. U. S. Nat. Mus., Vol. 16, p. 119, 1893. "Synopsis of North American Invertebrates, The Actiniaria," by G. H. Parker, Am. Nat., Vol. 34, p. 747, 1900. "The Actinians of Porto Rico," by J. E. Duerden, Bull. U. S. Fish. Com., Vol. 20, p. 323, 1900.

8 mesenteries (protocnemes), 2 additional pairs of rudimentary protocnemes and a few small metacnemes being also present; outer surface characterized by 8 longitudinal ridges and often incrusted with sand and other foreign substances: 4 genera and about 20 species.

1. **Edwardsia** Quatrefages. Form slender, prismatic; tentacles 16 or less in 2 circles of 8 each, of which the outer circle is the larger; 2 siphonoglyphs: several species.

E. elegans Verrill. Number of tentacles 16; length 25 mm.: north of Cape Cod, in shallow water.

Fig. 225
Edwardsiella sipunculoides (Torrey).

E. leidyi Ver. Number of tentacles 16; length 30 mm.; diameter 1.5 mm.; parasitic in *Mnemiopsis leidyi:* Vineyard Sound and southwards; common.

2. **Edwardsiella** Andres. Form cylindrical; tentacles more than 16, usually at least 24, of which 8 are in the outer row: several species.

E. lineata Verrill. Number of tentacles 18 to 30; length 25 to 35 mm.; diameter 3 mm.; color brown: from Vineyard Sound southwards, in 4 to 12 fathoms; common among worm tubes, rocks, etc.

E. sipunculoides Stimpson (Fig. 225). Tentacles 20 to 36; length 12 cm. extended; diameter 4 mm.; color brown: Cape Cod and northwards, in shallow water.

Division 2. CERIANTHEAE.

Solitary sea anemones, long and slender, usually imbedded in sand or mud, with numerous tentacles in 2 rows, an outer, marginal, and an inner, circumoral row, and with numerous mesenteries; retractor and sphincter muscles weak or wanting in the adult, ectodermal muscles acting as retractors; but 1 siphonoglyph present; ectoderm with numerous gland and nettle cells which discharge sufficient mucus and nematocysts to form a long tube in which the animal lives: several genera with about 20 species.

Cerianthus Delle Chiaje. Lower end rounded and provided with a terminal pore: 2 species on the Atlantic and 3 on the Pacific coast.

C. americanus* Verrill. Marginal tentacles up to 125 or more; length of body up to 60 cm. extended; diameter 25 mm.; color brown: Cape Cod to Florida, in shallow water.

* See "The Structure of Cerianthus americanus," by J. P. McMurrich, Jour. Morph., Vol. 4, p. 131, 1890.

C. borealis* Ver. (Fig. 226). Tentacles very numerous; length of body up to 45 cm. extended; diameter 4 cm.: Long Island Sound to Bay of Fundy, in 7 to 150 fathoms; very rare south of Cape Cod.

Fig. 226
Cerianthus borealis (Kingsley).

Division 3. ZOANTHEAE.

Usually colonial sea anemones springing from an incrusting or stolon-like base; tentacles numerous, in 1 or 2 rows; mesenteries with a characteristic arrangement; 1 siphonoglyph present: about 8 genera and over 75 species, many of which are epizoic in habit, being incrusted on hermit crabs, sponges, hydroids, etc.; several genera.

1. Zoanthus Cuvier. Polyps claviform or cylindrical, elongate, usually rising singly from a network of stolons, and with no foreign bodies incrusted in their outer surface: numerous species.

Z. sociatus (Ellis). Polyps about 17 mm. high, springing from stolons or rarely an incrusting membrane, or from one another; tentacles 48 to 60: West Indies.

2. Epizoanthus Gray. Surface of body incrusted with sand and other foreign bodies; colony consists of several individuals rising from a membrane-like base which may cover a variety of living or non-living objects.

E. americanus Verrill (Fig. 227). Tentacles 38 or more; height of polyp 25 mm.: attached to stones or to hermit crabs in 20 to 400 fathoms, from New Jersey to Gulf of Saint Lawrence.

Fig. 227
Epizoanthus americanus (from Parker).

Division 4. HEXACTINIAE.

Solitary sea anemones, often of large size, with 6 pairs of mesenteries in the simplest forms, and approximate multiples of 6 in the higher ones, with usually 2 siphonoglyphs and a large number of tentacles; the animals usually fasten themselves temporarily to rocks, etc., by the flat foot, which acts like a sucker, and can move slowly from place to place: about 300 species.

* "Description of Cereanthus borealis Verrill," by J. S. Kingsley, Tufts College Studies, Vol. 1, p. 345, 1904.

Key to the families of *Hexactiniae* here described:

a_1 Pedal disc absent; usually sand dwellers.....1. HALCAMPIDAE
a_2 Pedal disc present.
b_1 Acontia absent.
c_1 Body tuberculated.....2. BUNODIDAE
c_2 Body not tuberculated.....3. PARACTIDAE
b_2 Acontia present.....4. SAGARTIIDAE

FAMILY 1. HALCAMPIDAE.

Pedal disc absent, the lower end being rounded or pointed and often swollen; mesenteries few in number, 6 pairs of protocnemes with 4 to 6 pairs of metacnemes being present; no special sphincter; tentacles 12 to 36: about 6 genera.

1. **HALCAMPA** Gosse. Body long and slender with longitudinal grooves and composed of 3 sections, an oral retractile portion, an inter-

Fig. 228

Fig. 229

Fig. 230

Fig. 228—*Halcampa farinacea* (from Parker). Fig. 229—*Bicidium parasiticum* (from Parker). Fig. 230—*Eloactis producta* (from Parker).

mediate portion usually coated with sand, and a pedal portion; 2 siphonoglyphs: several species, which live in sand and mud.

H. farinacea Verrill (Fig. 228). Tentacles 12 in 2 rows; body 25 mm. long extended and 3 mm. in diameter; color whitish, with longitudinal bands of brown; disc yellow: north of Cape Cod, in 8 to 10 fathoms.

2. **BICIDIUM** Agassiz. Twelve tentacles in a single row; mouth with a proboscis (conchula): several species.

B. parasiticum Ag. (Fig. 229). Body 30 mm. long extended and 6 mm. thick: parasitic on *Cyanea,* fixing itself by the mouth on the manubrium, subumbrella, or in the gastrovascular cavity; also in the sand: Cape Cod to Bay of Fundy.

3. **ELOACTIS** Andres. Body slender and very contractile; tentacles short and blunt or capitate and in two rows: 5 species.

E. producta And. (Fig. 230). Tentacles 20; body with 20 longitudinal ridges, 25 cm. long extended; diameter 18 mm.; color whitish or salmon: South Carolina to Cape Cod, buried in the sand or on the under side of stones in shallow water.

Family 2. BUNODIDAE.

Body often of large size, with a strong entodermal sphincter and usually a tuberculated outer surface: about 10 genera.

1. Bunodes Gosse. Outer surface with longitudinal rows of tubercles; tentacles rather short, retractile: 15 species.

B. stella Verrill (Fig. 231). Body 50 mm. high; oral disc 35 mm. wide; tentacles 48 to 72: north of Cape Cod, in shallow water.

2. Aulactinia Verrill. Outer surface with longitudinal rows of tubercles on upper half; lower half smooth: several species.

A. capitata Ver. Body 15 cm. high and 35 mm. in diameter; tentacles 96 in 4 circles: North Carolina to Florida, in shallow water.

3. Epiactis Verrill. Outer surface of body with a band of egg pits around its middle: 1 species.

E. prolifera Ver. (Fig. 232). Height 10 mm.; diameter 12 mm.;

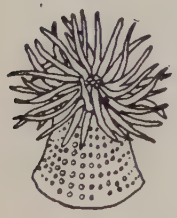

Fig. 231

Fig. 232

Fig. 233

Fig. 231—*Bunodes stella* (from Parker). Fig. 232—*Epiactis prolifera* (from Parker). Fig. 233—*Tealia crassicornis* (from Parker).

tentacles about 96; egg pits as many as 30 or 40: Pacific coast from Puget Sound to San Francisco.

4. Tealia Gosse. Outer surface with scattered tubercles; body short and thick and more or less covered with sand, bits of shell, etc.; tentacles short and thick: several species.

T. crassicornis (O. F. Müller) (Fig. 233). Height 5 cm.; diameter 12 cm.; tentacles 160; color reddish with gray tubercles: northern seas, extending southward to Puget Sound and Cape Cod, in 14 to 40 fathoms; Europe.

Family 3. PARACTIDAE.

Anemones with a strong sphincter and a smooth outer surface: about 10 genera.

1. Paractis Milne-Edwards. Body with longitudinal grooves; tentacles slender, not very numerous, and all of equal length: several species.

P. rapiformis (Lesson) (Fig. 234). Body 80 mm. high extended, and 25 mm. in diameter; surface nearly smooth, pinkish in color; pedal

disc small; tentacles short: buried in the sand near low water mark; from Cape Cod to Hatteras; Europe.

Family 4. SAGARTIIDAE.

Anemones with a sphincter and with acontia; cinclides usually present; tentacles usually numerous: 20 genera.

1. **Sagartia** Gosse. Outer surface smooth; oral disc not lobed; cinclides present; tentacles in 3 or 4 cycles and retractile: many species.

S. luciae Verrill. Body 8 mm. high, 6 mm. in diameter, olive green in color, with about 12 longitudinal orange stripes; 84 tentacles in 4 rows: very common on stones and shells in tide pools; Long Island Sound to Massachusetts Bay and farther north.

S. leucolena Ver. Body elongate, 6 cm. long extended, 10 mm. in diameter, with a translucent flesh color; tentacles 96, in 4 rows: common

Fig. 234

Fig. 235

Fig. 236

Fig. 234—*Paractis rapiformis* (from Parker). Fig. 235—*Sagartia modesta* (from Parker). Fig. 236—*Metridium dianthus* (from Parker).

under stones and in the sand in shallow water from North Carolina to Cape Cod.

S. modesta Ver. (Fig. 235). Height 6 cm.; diameter 15 mm.; color yellowish; tentacles 60: buried to the tentacles in sand; Long Island and Vineyard Sounds.

2. **Metridium** Oken (*Actinoloba* Blainville). Outer surface smooth; pedal disc broad; oral disc lobed; cinclides present; tentacles very numerous and short: several species.

M. dianthus (Ellis) (*M. marginatum* Lesson) (Fig. 236). Length up to 10 cm., width 7 cm.; color variable, but usually brownish or yellowish: the largest and one of the commonest sea anemones on the Atlantic coast; New Jersey to Labrador, from low-water mark to 90 fathoms; Pacific coast; Europe.

3. **Adamsia** Forbes. Pedal disc adherent, the animals fixing themselves to the shells of hermit crabs or to crustaceans; a band of cinclidial tubercles around the base of the column, the rest of which is smooth.

A. tricolor Lesson. Height 75 mm.; diameter 45 mm.; tentacles 500 or more in large individuals: on hermit crabs; North Carolina to Florida, in shallow water.

Suborder 3. MADREPORARIA.*

The stony corals. The polyps are either solitary or colonial, and secrete from the ectoderm a very hard, calcareous skeleton (Fig. 237). This usually takes the form in each case of a cup into which the polyp or zooid can retract itself and which consists essentially of a system of radial vertical plates or septa projecting into the interior of the polyp, but always covered with the three layers of the body wall and alternating, in a general way, with the mesenteries (Fig. 238). The outer edges of these stony septa usually join an outer wall called the theca, which is the outer part of the cup in which the polyp sits. In the middle of the cup is often a central column (columella). As the polyps grow, they constantly build up the theca and the septa, withdrawing from the

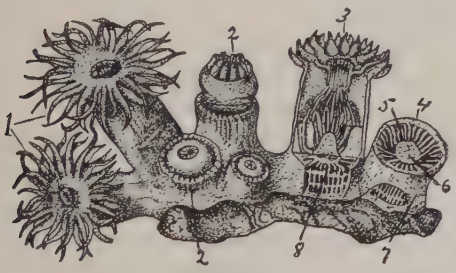

Fig. 237

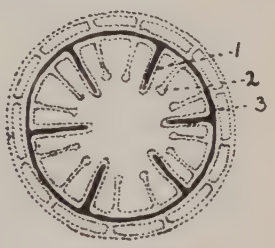

Fig. 238

Fig. 237—Diagram of a coral colony (Boas). 1, extended coral polyp; 2, retracted coral polyp; 3, longitudinal section of a coral polyp; 4, calcareous cup from which the polyp has been removed; 5, columella; 6, septa; 7, theca; 8, tabulae. Fig. 238—Cross section of a coral, the stony skeletons being black (Boas). 1, septum; 2, mesentery; 3, theca.

deeper portions, which may become cut off by horizontal partitions—the tabulae. The colonies increase in size by growth and budding of the polyps, producing, in this way, the coral reefs which are such an important feature of tropical seas. All the reef-forming corals live in shallow water, 300 feet being the maximum depth in which they are found.

The suborder contains over 1,000 species, grouped in 3 divisions. Most of the species are found in tropical or subtropical waters, a few, however, occurring in temperate and even in Arctic seas.

Key to the divisions of *Madreporaria:*

a_1 Coral porous; septa not more than 12.....1. Perforata
a_2 Coral solid; septa usually numerous.
b_1 Septa without cross bars .....2. Aporosa
b_2 Septa with cross bars.....3. Fungacea

* See "The Florida Reefs," by L. F. Pourtalès, Bull. Comp. Zool., Vol. 6, p. 102, 1880. "The Tortugas and Florida Reefs," by A. Agassiz, Mem. Am. Acad., Vol. 2, 1882. "The Stony Corals of the Porto Rican Waters," by T. W. Vaughan, Bull. U. S. Fish. Com., Vol. 20, Pt. 2, p. 291, 1900.

Division 1. PERFORATA.

Corals wholly or partly porous or reticulate; zooids small with not more than 12 septa (Fig. 239), which are sometimes indistinct: 2 families, which include many important reef-building corals.

Fig. 239—Cups of *Porites* showing septa (Vaughan).

Family 1. ACROPORIDAE.

Colony usually branched, the coral being porous and containing canals connecting the polyps, which are usually small and crowded; mesenteries in bilateral pairs; cup small, deep, without columella and with 6 or 12 septa: about 8 genera and over 150 species.

Acropora L. (*Madrepora* L.). Colony branched, being either flabellate, radiate or thick and little branched except towards the periphery; zooids projecting; terminal polyps with 6, lateral polyps with 12 tentacles; color usually due to symbiotic algae: many species, in most tropical seas; 1 species in the West Indies.

A. muricata L. Colony large (1 m. by 50 cm.), and usually spreading, with 3 common varieties; *A. cervicornis* Lamarck, which is loosely branched, *A. prolifera* Lam. (Fig. 240), in which the branches are more crowded and often fused together, and *A. palmata* Lam., made up of large fan-shaped masses: West Indies and Florida.

Fig. 240
Acropora muricata (Vaughan).

Family 2. PORITIDAE.

Colony with a variety of forms, usually incrusting and massive, often forming thick branches, but rarely dendritic; zooids small and close together; coral porous and made up of a system of trabeculae and cross bars: about 12 genera and 100 species, many of which are reef-building.

Porites* Lamarck. Cup with about 12 short septa; columella present but often indistinct: many species, 2 West Indian; often forming very large colonies.

P. porites (Pallas). Colony more or less branching, there being 3 well-marked varieties; *P. clavaria* Lam., consisting of very thick

* See "On the Genus Porites," by R. Rathbun, Proc. U. S. Nat. Mus., Vol. 10 p. 354, 1887.

upright branches; *P. furcata* Lam. (Fig. 241), in which the branches are slender, and *P. divaricata* Lesueur, in which the branches are quite

Fig. 241

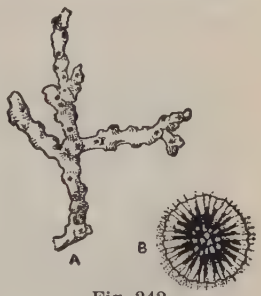

Fig. 242

Fig. 241—*Porites porites* (Vaughan). Fig. 242—*Oculina diffusa* (Vaughan). A, the entire colony; B, a single cup, showing the septa.

slender (6 mm. in diameter, or less) and spreading: West Indies and Florida.

P. astreoides Lam. Colony not branching, but more or less globose, often with thick lobes: West Indies and Florida.

Division 2. APOROSA.

Coral solid; cup with usually numerous septa (Fig. 242, B): about 10 families.

Key to the families of *Aporosa* here described:

a_1 Mostly solitary corals.....1. Turbinoliidae
a_2 Colonial corals.
b_1 Zooids not contiguous.....2. Oculinidae
b_2 Zooids close together or confluent.....3. Astreidae

Family 1. TURBINOLIIDAE.

Mostly solitary corals, with numerous septa and without a true theca, imbedded in the sand or attached to some object: about 50 genera and several hundred species, of which the greater number are fossil.

Flabellum Lesson. Coral solitary, flattened more or less, tapering towards the base, which is attached in youth but may become detached later: over 50 species.

F. goodei Verrill. Height up to 80 mm.; greater diameter 12 cm., lesser 43 mm.; color in life salmon with brown stripes; a very fragile coral: Newfoundland to Florida, in 200 to 500 fathoms.

Family 2. OCULINIDAE.

Colony usually dendritic, with large zooids more or less widely separated from one another; coral compact with 12 to 48 distinct septa and usually a columella: about 22 genera.

Oculina Lamarck. Colony dendritic with spirally arranged zooids: many species.

O. diffusa Lam. (Fig. 242). Colony very much branched, the branches forming an angle of about 30°; cups 3 mm. in diameter: North Carolina to Florida, often common in shallow water.

Family 3. ASTRÆIDAE.

Usually colonial corals with the zooids so crowded that there is little or no space between them, and in some cases being confluent; colony compact and massive or erect; a few species are solitary: hundreds of genera and species, being the largest family of corals.

Fig. 243—*Astrangia danae* (from Davenport).

1. Astrangia Edwards and Haime. Colony incrusting, the zooids being distinct and more or less isolated, with 6 septa of the 1st cycle, 6 smaller ones of the 2nd, and incomplete 3rd and 4th cycles: 4 American species.

A. danae Agassiz (Fig. 243). Colony small, containing from 5 to 30 individuals, incrusted on stones, shells, etc., up to 10 cm. in diameter and 5 cm. high: Florida to Cape Cod, in shallow water; common.

2. Orbicella Dana. Colony usually massive with zooids distinct and separated by deep concave spaces: numerous species.

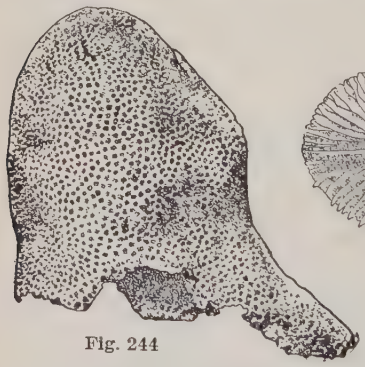

Fig. 244

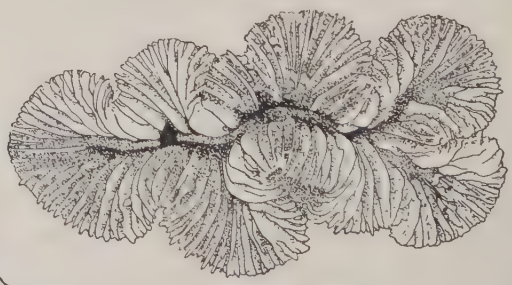

Fig. 245

Fig. 244—*Orbicella annularis* (Vaughan).
Fig. 245—*Meandrina meandrites* (Vaughan).

O. annularis (Lamarck) (Fig. 244). Colony globose; cups 2 mm. in diameter with 12 septa of the first and 12 of the second order: Florida and the West Indies.

3. Meandrina Lamarck. Zooids confluent; tentacles, mesenteries, and septa arranged in rows; the mouths of the polyps distinct: numerous species.

M. meandrites (L.) (Fig. 245). Colony 4 to 8 cm. or more long and half as broad with a single large main groove and large septa; columella present: West Indies and Florida.

M. sinuosa Lesueur (*Platygyra viridis* Les.) (Fig. 246). Brain-coral. Colony incrusting and massive, 25 cm. in diameter or more; surface made up of numerous sinuous ridges, which are the septa, and grooves: West Indies and Florida.

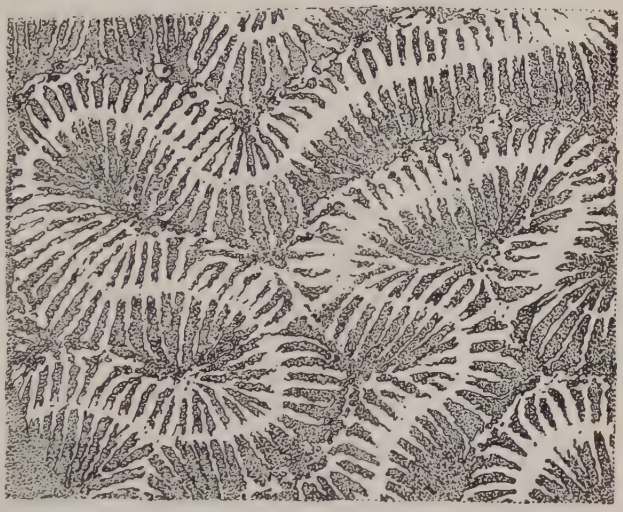

Fig. 246—*Meandrina sinuosa* (Vaughan).

DIVISION 3.
FUNGACEA.

Solitary or colonial corals in which the septa are joined by cross bars or synapticula: 5 families.

FAMILY 1. PLESIOFUNGIIDAE.

Coral solitary or colonial, with additional ridges (dissepiments) on the inner wall of the cup between the septa: about 15 genera.

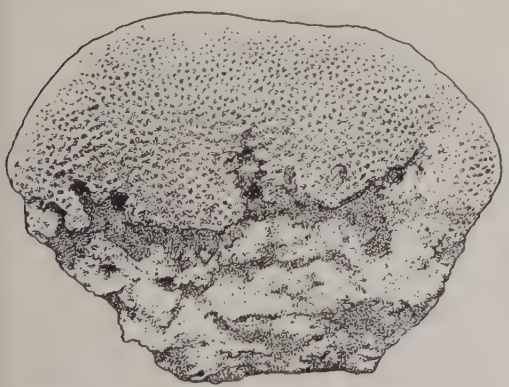

Fig. 247—*Siderastrea siderea* (Vaughan).

SIDERASTREA* Blainville. Colony with distinct zooids, crowded and more or less polygonal, and forming rounded, unbranched masses.

S. radians (Pallas). Cups about 3 mm. by 2 mm., rounded, with the fourth cycle of septa incomplete: West Indies.

S. siderea (Ellis and Solander) (Fig. 247). Cups about 5 mm. by 4.5 mm., subhexagonal, with 4 complete cycles of septa: West Indies.

* See "The Coral Siderastræa," by J. E. Duerden, Pub. Carn. Inst., No. 20, 1904.

Family 2. FUNGIIDAE. (Mushroom Coral.)

Coral solitary or colonial, often of large size, flat and disc-like in shape with numerous septa; the living disc covers the septa and from its surface rise very numerous tentacles; the embryo gives rise to a conical coral called a trophozooid, the upper part of which expands, breaks off, and becomes the adult coral, a process which may repeat itself a number of times: about 12 genera.

Fungia Dana. Coral solitary and of large size, convex on the upper and concave on the lower side; without siphonoglyph: numerous species, 1 American.

F. elegans Verrill. Coral round and thick, about 6 cm. in diameter: Gulf of California.

Subphylum 3. CTENOPHORA.*

Very soft and delicate jellyfishes which live mostly in the surface waters of the sea. The body is usually more or less spherical, pear-shaped or cylindrical in shape, and is both radially and bilaterally symmetrical. Its outer surface is without hard skeletal structures and bears eight longitudinal bands of cilia, which are the characteristic "combs" (Fig. 249) and the organs of locomotion. Each of these bands is composed of a series of transverse plates formed by the fusion of long cilia. The animal has an oral and an aboral end which are opposite each other. At the former is the mouth, an elongated slit which leads into a deep flattened cavity lined with ectoderm, called the stomach. It is into this space that the food is taken and digested. At the aboral end of the body is a slight cavity which is connected with the eight bands of cilia by four ciliated grooves, and in which are calcareous concretions and sensory cells. The sense organ thus formed is called the statocyst and is an organ of equilibration.

Many ctenophores have a pair of long retractile tentacles which project from a pair of deep pockets in opposite sides of the body (Fig. 249). These tentacles have short branches or pinnae and their ectoderm is provided with numerous peculiar adhesive cells which aid in capturing and killing the prey; they are very retractile, and can be wholly or partially withdrawn into the pockets. Other tentacles and projections are also present in certain species.

* See "Ctenophorae," by L. Agassiz, Contributions to the Natural History of the United States, Vol. 3, p. 155, 1860. "Die Ctenophoren des Golfes v. Neapel," by C. Chun, Fauna u. Flora d. Golfes v. Neapel, Vol. 4, 1880. "The Ctenophores of the San Diego Region," by H. B. Torrey, Univ. of Cal. Pub., Vol. 2, p. 45, 1904. "Ctenophores of the Atlantic Coast of North America," by A. G. Mayer, 1911.

It will be seen that a longitudinal plane passed through the body which includes the mouth and stomach divides the body into two symmetrical halves; a transverse plane, on the other hand, reveals a radial type of structure.

The gastrovascular space consists of a complex system of narrow tubes (Fig. 248) lined with entoderm which join the inner end of the stomach, and communicate with the outside also by means of either one or two pores at the aboral end of the body. Eight of these tubes which lie immediately beneath the eight longitudinal bands of cilia form the most important part of the system. The space between these gastrovascular tubes and the outer ectoderm is filled with the soft jelly-like mesenchyne which differs from the mesoglea of the other cœlenterates in that it arises as the result of the proliferation of definite cells during the early development of the animal; in it are nuclei and muscle fibers.

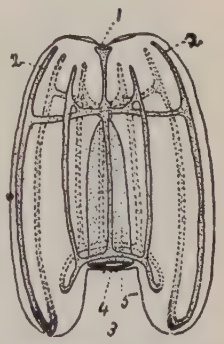

Fig. 248 — Diagram of a ctenophore, showing the canal system (Mayer). 1, aboral end with statocyst; 2, longitudinal canals; 3, oral end of body; 4, mouth; 5, stomach.

All ctenophores are hermaphroditic, the gonads consisting of a pair of bands, one male and the other female, which lie side by side against the outer wall of the main longitudinal canals of the gastrovascular space, the genital products reaching the outer sea water through the mouth. The young animal passes through a complex metamorphosis before reaching the adult condition; but there is no alternation of generations. Certain genera may exhibit pædogenesis, reproducing in the larval stage, and again as adults.

Ctenophores are common marine animals, often occurring in enormous schools. They are noted for their delicacy and beauty, the rapidly vibrating combs refracting the light and showing a rapid play of changing colors. They are also often highly phosphorescent at night. Their food consists of crustaceans, fishes, and other small animals, often including their own kind. The subphylum contains two classes and less than 100 species, 21 of which occur off the Atlantic coast.

Key to the classes of *Ctenophora:*

a_1 Either tentacles or oral lobes present.....1. TENTACULATA
a_2 Tentacles and oral lobes absent.....2. NUDA

CLASS 1. TENTACULATA.

A pair of long tentacles present, in certain cases in the larval stage only, oral lobes being then present in the adult: 3 orders.

Key to the orders of *Tentaculata:*

a_1 Body more or less globose or cylindrical.
b_1 Long tentacles present.....1. Cydippida
b_2 No tentacles in adult animal; oral lobes present.....2. Lobata
a_2 Body compressed and ribbon-like.....3. Cestida

Order 1. CYDIPPIDA.

Body spherical or cylindrical or compressed in the plane transverse to the tentacular axis; tentacles very long, on opposite sides of the body, springing each from a deep pocket: several families.

Fig. 249

Pleurobrachia pileus (Mayer). T, tentacles; C, combs; other references as in Fig. 248.

Family PLEUROBRACHIIDAE.

Body spherical or ovoid, with the 8 ribs of equal length: 4 genera.

1. Pleurobrachia Fleming. Body but very little compressed; combs rather long but not reaching the oral or aboral areas: about 8 species.

P. pileus (Fabricius) (*P. rhododactyla* Agassiz; *P. bachei* A. Agassiz) (Fig. 249). Body about 20 mm. long and 18 mm. wide, and very transparent; tentacles about 15 cm. long and white or rose-colored, with long pinnae: from the south side of Long Island to Greenland; breeds in August and September; Europe; Pacific coast.

P. brunnea Mayer. Body 12 mm. long, ovoid; stomach of an opaque yellowish-brown color; each tentacle with a knob-shaped end: coast of New Jersey; rare.

2. Mertensia Lesson. Body much compressed, the tentacular axis being the wider; the 4 subtentacular combs longer than the 4 subventral ones: 1 American species.

M. ovum (Fabricius). Body about 5 cm. long and ovoid in outline; tentacles, combs, and sense organ light pink in color: Arctic Ocean to New Jersey; rare south of Cape Cod.

Order 2. LOBATA.

Body ovate, compressed in the plane transverse to that of the stomach; mouth wide, with a large and prominent oral lobe on each side of it; at the base of each lobe is a pair of long projections called auricles; tentacles of the ordinary kind wanting in the adult, but numerous, delicate, filamentous tentacles may fringe the margin of the mouth and the auricles; aboral sense organs sunk in a pit; a larval cydippiform stage present, which has a pair of tentacles issuing from pockets and in certain genera may have sexual reproduction: several families.

Family 1. BOLINOPSIDAE.

Oral lobes of medium size; auricles short: 3 genera.

Bolinopsis Agassiz (*Bolina* Mertens). With the characteristics of the family; combs not prolonged onto the oral lobes: 6 genera.

B. infundibulum (O. F. Müller) (*B. alata* Ag.) (Fig. 250). Body up to 15 cm. long, of a transparent bluish-white color: from Vineyard Sound to Labrador, often very common north of Cape Cod.

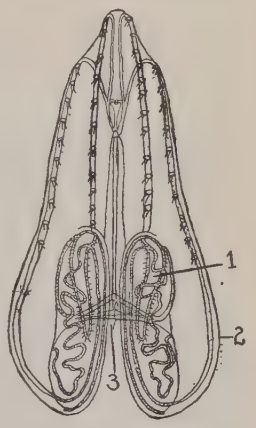

Fig. 250—*Bolinopsis infundibulum* (Mayer). 1, auricle; 2, oral lobe; 3, mouth.

Family 2. MNEMIIDAE.

Lobes large, each bounded on each side by a deep lateral furrow which extends to the aboral end of the body; auricles long and slender: 4 genera.

Mnemiopsis Agassiz. Auricles long and large; combs prolonged onto the lobes almost to their oral ends: 3 species.

M. leidyi A. Agassiz (Fig. 251). Body up to 10 cm. long and very transparent, at night very phosphorescent: Long Island and Vineyard Sounds and south to the Carolinas, often in large swarms; often parasitized by a sea anemone, *Edwardsia leidyi.*

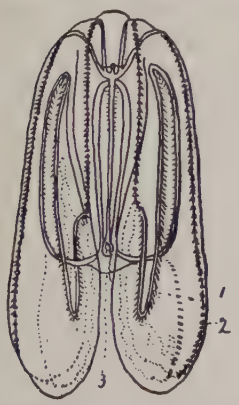

Fig. 251—*Mnemiopsis leidyi* (Mayer). 1, auricle; 2, oral lobe; 3, mouth.

M. gardeni Ag. Length 4 cm.; lobes rather small and covered with warts; body translucent or bluish in color: Chesapeake Bay to Florida; abundant.

Order 3. CESTIDA.

Body flattened in the plane of the tentacles and so enormously extended in the plane of the stomach that it has the shape of a ribbon which may be a meter or more long by 8 cm. high; 4 of the combs (the subtentacular) are very short, the other 4 are very long; tentacles more or less rudimentary, tentacle sheaths deep: 2 genera.

Cestus Lesueur. With the characters of the order: 2 species.

C. veneris Les. Venus' girdle. Body transparent, shimmering with violet, blue, or green: tropical seas, occasionally brought to our shores by the Gulf Stream, fragments of the animal being occasionally seen on the New England coast.

Class 2. **NUDA.**

Tentacles absent: 1 family.

Family BEROIDAE.

Body conical or ovate and compressed, with a mouth and stomach so very wide that the body is much the shape of a compressed thimble; combs extend the length of the body; a network of canals throughout the body which ramify off from the gastrovascular canals: 2 genera with few species; they are cosmopolitan, often occurring in large swarms, and are noted for their voracity, sometimes swallowing other ctenophores larger than themselves.

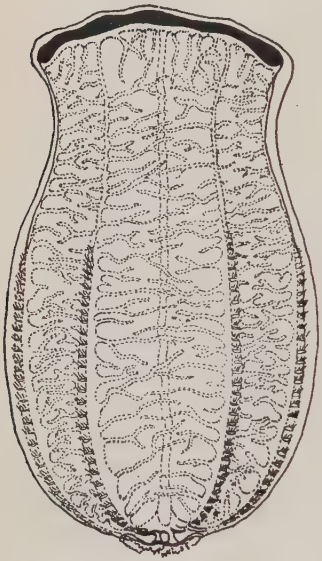

Fig. 252—*Beroe cucumis* (Mayer).

Beroë Browne (*Idyia* Fréminville). Body more or less conical or ovoid: about 14 species.

B. ovata Chamisso and Eysenhardt Body often tapering from the mouth to the aboral pole and much compressed, 10 cm. long, pink in color towards the north, milky white towards the south: Chesapeake Bay to Florida; cosmopolitan; abundant.

B. cucumis Fabricius (*B. roseola* Agassiz) (Fig. 252). Body 10 cm. long, 9 cm. wide and 6 cm. thick and rose color: Vineyard Sound to Labrador, often very plentiful towards the north.

PHYLUM III.

VERMES. (The Lower Worms.*)

Worms of primitive structure and often of small size, usually without paired locomotory appendages or a distinct head, and with non-metameric and often permanently ciliated bodies. The animals are usually sluggish of movement and in very many cases either sessile or parasitic.

The *Vermes* form a polymorphic group of animals, the eight subphyla of which do not necessarily bear a close genetic relationship to one another. They, however, have many structural features in common and many of the classes bear a definite relation to the trochophore larva which justifies the placing of them in a common group. This would rank immediately beneath the annelids and the other groups in which the trochophore represents an ancestral form.

The class *Vermes,* as formed by Linnæus, included all invertebrate animals except arthropods. Lamarck divided the invertebrates into several classes, of which one was *Vermes,* including in it both the unsegmented and segmented worms. This arrangement, although it has been followed by Claus, Hertwig, and other modern authors, is not now usually adopted, and the *Vermes,* when used as the name of a phylum, generally include the lower worms alone.

The phylum contains 8 subphyla.

Key to the subphyla of *Vermes:*

a_1 Animals mostly non-burrowing.
  b_1 Animals mostly locomotory.
    c_1 Animals mostly not minute and very often parasitic.
      d_1 Flattened worms; very many parasitic.....1. Plathelminthes
      d_2 Round and thread-like worms; often parasitic....2. Nemathelminthes
    c_2 Animals minute and aquatic.
      d_1 Crown of cilia at forward end; animals mostly in fresh water. 3. Trochelminthes
      d_2 No external cilia; animals marine.....7. Chætognatha
  b_2 Animals sessile.
    c_1 Animals colonial.....4. Bryozoa
    c_2 Animals not colonial.
      d_1 Animals with a two-valved shell.....5. Brachiopoda
      d_2 Animals form tubes.....6. Phoronidea
a_2 Marine worms which burrow in the sand and mud.....8. Sipunculoidea

* See "Vermes," by H. Pagenstecher and M. Braun, Bronn's Klassen und Ordnungen des Thierreichs, Band 4, 1893. "Textbook of the Embryology of Invertebrates, Part I," by E. Korschelt and K. Heider, translated by E. L. Mark and W. M.

Subphylum 1. PLATHELMINTHES.

Flatworms. Flattened or in some cases cylindrical worms of soft texture which are found in the water or in moist earth, or which live as parasites in animals or plants. The body is without a distinct head or paired appendages and is not metamerically segmented. A body cavity is also wanting in most of them, the spaces between the internal organs being secondarily filled with a vesicular connective tissue, called parenchyma. The outer surface of the body is either a ciliated epithelium or a thick unciliated cuticula and no hard skeletal structures are present except chitinous hooks and spines. The mouth is usually in the ventral surface in the *Turbellaria* and at the front end of the body in the other groups, and an anus is not present, except in the *Nemertea.* A mouth and an alimentary tract are wanting in the tapeworms. The nervous system consists of paired cerebral ganglia forming a brain at the forward end and nerves extending to various parts of the body. Special sense organs, when present, consist of simple eyes, tentacles, or statocysts. The excretory system consists of slender tubes extending throughout the parenchyma, the final branches of which end in flame cells. It opens to the outside either through a single pore or through several paired pores. No special respiratory organs are present, and except in the *Nemertea,* no circulatory organs or blood fluid. The reproductive organs are complex, except among the *Nemertea,* hermaphroditism being general. Asexual reproduction by budding or fission is common in certain groups.

History.—Certain of the parasitic flatworms have been known from time immemorial. Linnæus included all invertebrates except arthropods (his *Insecta*) in the class *Vermes,* one of the orders of which was the *Intestina,* or worms proper. Cuvier (1798) first called attention to the fundamental distinction between the unsegmented and the segmented worms, to the former of which Rudolphi (1808) gave the name *Entozoa,* most of the unsegmented worms as then known being parasites. It was this author who, following however Zeder in his general classifications, laid the foundation of our present classification of parasitic worms, of which he formed five orders, the roundworms or *Nematodes,* the *Acanthocephala,* the *Trematodes,* the tapeworms or *Cestodes,* and the bladderworms or *Cystici.* F. S. Leuckart and von Baer showed that these groups did not necessarily bear a genetic relationship to one another. Vogt in 1851 first joined the four orders of flatworms to form a class which he

Woodworth, 1895. "Flatworms and Mesozoa, Nemertines, Thread-Worms and Sagitta, Rotifers," etc., Cambridge Natural History, Vol. 2, 1896. "Les Vermidiens," by Delage et Hérouard, Traité de Zool. Concrète, Vol. 5, 1897. "A Student's Textbook of Zoology," Vol. 1, by Adam Sedgwick, 1898. "A Treatise on Zoology, Part 4," edited by E. Ray Lankester, 1901.

called *Platelmia,* while of the three orders of roundworms he formed the class *Nematelmia,* an arrangement which is still maintained.

The subphylum contains 4 classes.

Key to the classes of *Plathelminthes:*

a_1 No anus; no blood vessels; animals mostly hermaphroditic, with very complex genital organs.

b_1 Animals with rare exceptions free-living; body ciliated externally. 1. TURBELLARIA

b_2 Animals parasitic; not ciliated externally; mouth when present at forward end (with some rare exceptions).

c_1 Intestine and mouth present; animals small and unsegmented. 2. TREMATODES

c_2 Intestine and mouth absent; animals usually long and segmented. 3. CESTODES

a_2 Anus, anterior proboscis, and blood vessels present; animals mostly unisexual and free-living, usually long and bandlike.....4. NEMERTEA

CLASS 1. TURBELLARIA.*

Soft, free-living flatworms, mostly under an inch in length, which are found either in the water creeping slowly over stones or plants or living in moist places on the land. The body is flat in shape and usually elongate, but in some cases nearly circular. The external surface is ciliated and from it is exuded the slimy secretion of numerous glands, in which are often contained minute rod-like bodies called rhabdites which are produced in certain glandular cells either of the integument or of the parenchyma. A few turbellarians possess functional nettle cells which, however, they have acquired from hydrozoans they have eaten, and a few have adhesive papillae or suckers.

No body cavity is present, the spaces between the organs being filled with the parenchyma. The mouth (Fig. 263) is usually near the middle of the ventral surface but may in the different species vary in position from the forward to the hinder end. It opens into a muscular pharynx which is usually of large size and one of the most prominent organs in the body: it can usually be thrust out of the mouth so as to form a proboscis by means of which the animal takes and often digests its food. An intestine is not present in the *Acœla:* in the other turbellarians it is either a tubular or a branched structure. An anus is not present, fecal matter being discharged through the mouth: in certain cases, however, the intestinal

* See "Rep. Invert. Vine. Sd.," by A. E. Verrill, Rep. U. S. Com. Fish. for 1871 and 1872. "Beob. über die Süsswasser Turbel. Nordam.," by W. A. Silliman, Zeit. f. wiss. Zool., Vol. 41, p. 48, 1885. "Turbellaria," by L. von Graff, Bronn's Kl. u. Ord., Vol. 4, Abt. 1, Acœla und Rhabdocœlida, 1904-08. "Turbellaria," by same. "Die Süsswasserfauna Deutschlands," 1909. "Vergleichung der Nordamerikanischen und Europäischen Turbellarienfauna," by same, Proc. Sev. Int. Zool. Cong., 1910. "Acœla, Rhabdocœla, und Allœocœla des Ostens der Vereinigten Staaten," &c., by same, Zeit. f. wiss. Zool., Vol. 99, p. 321, 1911.

branches open to the outside. The excretory system consists of a median canal or one to four pairs of longitudinal canals which open to the outside through usually paired pores and numerous small canals which penetrate the parenchyma in all directions and end in flame cells. The nervous system consists of a pair of ventral nerve cords, the anterior ends of which are enlarged to form a brain and which are joined by numerous transverse commissures. From the brain nerves go to the eyes and tentacles, when these organs are present, and also to the sensitive anterior end of the body.

The reproductive organs are very complex, the animals being with rare exceptions hermaphroditic, and differ somewhat in the various groups. The genital opening, which is either single or double, is in the ventral surface back of the mouth. Most species lay their eggs in capsules which are attached to plants or stones. A few reproduce also asexually, by transverse fission.

Habits and Distribution.—Most turbellarians are aquatic animals, living either in fresh or in salt water; only the *Terricola* are terrestrial. The largest aquatic form (*Leptoplana gigas*) may be 15 cm. in length, while the largest land turbellarians (*Bipaliidae*) may be 45 cm. long; the smallest forms are of microscopic size. They are with few exceptions carnivorous animals, living on small animals of all sorts: a few are parasitic.

History.—O. F. Müller in 1776 first separated the turbellarians and nemerteans from the other flatworms and placed them in the genus *Planaria.* Ehrenberg in 1831 named the group *Turbellaria.* In 1851 Vogt placed it with the other flatworms in the class *Platelmia.* The present arrangement of the group is due principally to von Graff and Lang. About 1,100 species of turbellarians are known, grouped in 2 subclasses.

Key to the subclasses of *Turbellaria:*

a_1 Minute marine forms without intestine.....1. Acœla
a_2 Intestine present.....2. Cœlata

Subclass 1. ACŒLA.*

Small, delicate marine turbellarians which are found free-swimming and also among the rocks and seaweed along the shore. They are often brightly colored, and in one genus at least (*Convoluta*) the pigment is due to a symbiotic alga. No intestine is present, the food, which consists of minute animals and plants, being introduced directly into the parenchyma. The mouth is often near the front end of the body, a proboscis being often absent. Eyes are usually absent, but a statocyst lies over the brain. The reproductive system is simple in structure, in many species

*See "Turbellaria, I. Acœla," by L. von Graff, Das Tierreich, 1905.

no vasa deferentia or oviducts being present. The subclass contains 2 families and about 40 species, of which 6 have been found in America.

Key to the families of *Acœla:*

a_1 One genital pore present.....1. PROPORIDAE
a_2 Two genital pores present.....2. CONVOLUTIDAE

FAMILY 1. PROPORIDAE.

But one genital pore present; position of mouth various: 5 genera and 14 species.

1. CHILDIA von Graff. Mouth in ventral surface behind the middle; pharynx absent; bursa seminalis absent; 2 male copulatory organs, each with a chitinous stilet: 1 species.

C. spinosa v. Gr. (Fig. 253). Length 1.4 mm.; color light yellow: Woods Hole.

2. ANAPERUS von Gr. Body elongate; bursa seminalis and pharynx absent: 1 species.

A. gardineri v. Gr. (Fig. 254). Length up to 6 mm.; width 1 mm.; color red, but yellow at the two ends: Woods Hole, with *Polychœrus caudatus,* which it resembles, but is much less numerous than it; movements rapid.

Fig. 253

Fig. 254

Fig. 253—*Childia spinosa* (von Graff). 1, statocyst; 2, ovary; 3, mouth; 4, penis; 5, genital pore.
Fig. 254—*Anaperus gardineri* (von Graff). 1, statocyst; 2, mouth; 3, ovary; 4, genital pore.

FAMILY 2. CONVOLUTIDAE.

Two genital pores present, the female pore being in front of the male; bursa seminalis present; mouth near the middle of the body: 5 genera and 25 species.

1. APHANOSTOMA Œrsted. Body cylindrical or flattened beneath and narrowed behind; mouth near the middle; statocyst present; eyes absent: 2 species.

A. diversicolor Œrst. (Fig. 255). Body very variable in shape, elliptical, with yellow at forward end; middle usually violet; length 1 mm.; width .25 mm.: Newport, R. I., and Woods Hole, among algae in shallow water, common; Europe.

2. **Polychœrus** Mark. Body broad and flat with either one or several caudal filaments: 1 species.

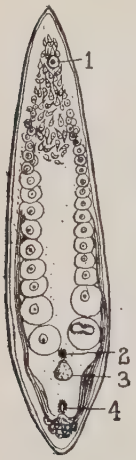

Fig. 255

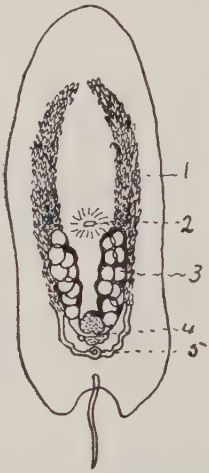

Fig. 256

Fig. 255—*Aphanostoma diversicolor* (von Graff). 1, statocyst; 2, female genital pore; 3, bursa seminalis; 4, male genital pore. Fig. 256—*Polychœrus caudatus* (Mark). 1, testis; 2, mouth; 3, ovary; 4, female genital pore; 5, male genital pore.

P. caudatus Mark (Fig. 256). Body with parallel sides and a deep notch in the hinder margin, from which 1 to 3 caudal filaments arise; color red; length 4 mm.; width 1.5 mm.: on stones along the beach from Casco Bay to Long Island Sound; often abundant; movements sluggish.

Subclass 2. CŒLATA.

Turbellarians with intestine: 3 orders.

Key to the orders of *Cœlata:*

a_1 Small forms with a straight intestine.....1. Rhabdocœlida
a_2 Usually larger forms with branched intestine.
b_1 Intestine with 3 main branches. 2. Tricladida
b_2 Intestine with many large branches. 3. Polycladida

Order 1. RHABDOCŒLIDA. (Fig. 257.)

Marine, fresh-water, and land turbellarians of small size in which the intestine is a straight and unbranched or at the most only slightly lobed tube or sac; yolk glands present or not; either 1 or 2 genital pores present: 23 families, grouped in 2 suborders with over 350 species, of which about 75 have been found in this country; about half the species marine.

Key to the suborders of *Rhabdocœlida:*

a_1 Intestine a straight tube.....1. Rhabdocœla
a_2 Intestine sac-shaped with irregular sides..2. Allœocœla

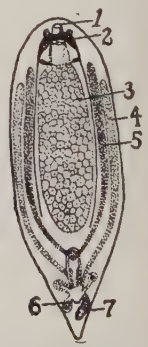

Fig. 257—Diagram of a rhabdocœlid (*Dalyellia*) (von Graff). 1, mouth; 2, brain; 3, intestine; 4, yolk gland; 5, testis; 6, genital pore; 7, ovary.

Suborder 1. RHABDOCŒLA.*

Body cylindrical, fusiform, filiform, or lamellate in shape; intestine a tube or sac, usually with straight sides; usually 2 eyes and occasionally sense pits and statocysts present; either a single median or a pair of excretory canals present; many forms reproduce asexually, by terminal budding: 16 families and 275 species, 48 American.

* See "Monographie d. Turbellarien, I. Rhabdocœlida," by L. von Graff, 1882.

Key to the families of *Rhabdocœla* here described:

a_1 Forward end not in form of a proboscis, or where a proboscis is present it cannot be retracted into a sheath.
  b_1 Ovary and yolk glands not distinct.
    c_1 Single median excretory trunk present.....1. CATENULIDAE
    c_2 A pair of excretory trunks present.....2. MICROSTOMIDAE
  b_2 Ovary and yolk glands distinct from each other.
    c_1 Pharynx sac-shaped and parallel to ventral surface.....3. DALYELLIIDAE
    c_2 Pharynx rosette-shaped and perpendicular to ventral surface. 4. TYPHLOPLANIDAE
a_2 Forward end in form of a proboscis which can be retracted into a sheath.
  b_1 One genital pore present.....5. POLYCYSTIDIDAE
  b_2 Two genital pores present.....6. GYRATRICIDAE

FAMILY 1. CATENULIDAE.

Mouth in ventral surface near forward end; no preoral branch of intestine; pharynx simple; excretory pore at hinder end, with a single median excretory trunk; testis and ovary median and single, the former in front of the latter; pigment eyes wanting; reproduction asexual as well as sexual, chains of individuals forming: 5 genera and about 25 species, 14 American.

1. **STENOSTOMUM*** Schmidt. Body colorless; intestine often colored brown, reaching almost to the hinder end of the body; a pair of ciliated sense pits in front of brain and 1 to 2 pairs of light-refracting organs behind it: 16 species, 5 American, all but one in fresh water.

S. leucops (Dugès). Chain consisting of 8 or less individuals up to 4 mm. long; light-refracting organs concave and 2 in number: eastern and central states; Europe; common.

S. grande Child (Fig. 258). Chain consisting of 4 to 6 individuals 2 to 2.6 mm. long; color orange yellow: in fresh and brackish water; common.

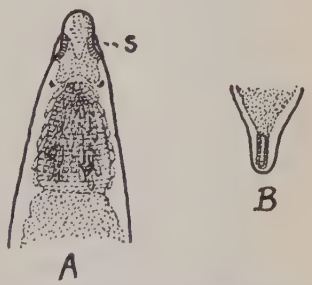

Fig. 258—*Stenostomum grande* (von Graff). A, anterior end with the sense pits (s); B, posterior end.

2. **RHYNCHOSCOLEX** Leidy. Forward end of cylindrical body elongated into proboscis-like appendage at the base of which are the mouth and a pair of sense pits: 2 species.

R. simplex Leidy. Body yellowish white, 5 mm. long: Philadelphia, at the bottom of clear brooks.

* See "Studies on Regeneration, Fission, and Regulation of Stenostoma," by C. M. Child, Arch. f. Entwick., Vol. 15, p. 187, 1902.

Family 2. MICROSTOMIDAE.

Mouth in ventral surface near forward end; pharynx simple; a pair of excretory tubes present; sense pits and usually pigmented eyes present: 35 species, 6 American.

1. Microstomum Schmidt. Preoral branch to intestine present; forward end of body not proboscis-like; hinder end tapering; chains of individuals formed: 15 species, in both fresh and salt water.

M. lineare (O. F. Müller). Body 1.8 mm. long; chain consisting of 18 individuals 7 mm. long; color yellowish or pink: 2 red eyes present; nettle cells present which have been derived from ingested hydras; hinder end with a tail on which are adhesive papillae: eastern states; Europe.

Fig. 259
Microstomum davenporti (von Graff).

M. davenporti von Graff (Fig. 259). Chain consisting of 4 individuals 1.5 mm. long; hinder end with numerous papillae; body colorless; intestine yellow; eyes absent: Long Island and Vineyard Sounds; on ulva and fucus.

Family 3. DALYELLIIDAE.

Large sac-shaped pharynx present; mouth near forward end of body; single genital pore present; ovary distinct from yolk glands, which are either 1 or 2 in number and usually unbranched; testes paired; pigment eyes usually present; penis usually with complex chitinous parts: about 70 species, mostly in fresh water; 17 American.

Dalyellia Fleming (*Vortex* Ehrenberg). Body rounded in front and tapering to a point behind; body not pigmented but often colored by *zoochlorellae;* 2 black eyes present, near which and the forward end is the mouth; genital pore in posterior third of body: 46 species, 13 American, all in fresh water.

D. armigera (Schmidt). Length 1 mm.; penis with 2 short chitinous rods, each of which has a spinose terminal branch: central and eastern states; common; Europe.

D. dodgei von Graff (Fig. 260). Penis with chitinous parts of unequal size and shape forming a transverse row fastened to a basal piece; length 1 mm.: the commonest species; eastern states; in fresh and brackish water.

Fig. 260
Dalyellia dodgei (von Graff).
1, mouth
2, pharynx
3, intestine
4, genital pore
5, egg.

Family 4. TYPHLOPLANIDAE.

Pharynx rosette-shaped, springing from the ventral wall of the intestine and perpendicular to the ventral body surface; ovary distinct

from yolk glands; testes paired; rhabdites usually prominent: 60 species, all except one in fresh water, 8 American.

1. **Typhloplana** Ehrenberg. Excretory ducts open with the mouth into a common space, which opens to the outside; without genital atrium; dermal rhabdites absent; testes very small, near the pharynx; eyes absent: 2 species.

T. viridata (Abildgaard). Body 1 mm. long, tapering at both ends, behind to a blunt point, colorless, but usually colored green by *zoochlorellae;* pharynx near middle of body with the genital pore behind it: eastern states; Europe.

2. **Castrada** Schmidt. Excretory ducts open as in *Typhloplana;* with genital atrium; eyes usually absent; dermal rhabdites absent: 27 species, in fresh water, 1 American.

C. hofmanni Braun. Body 1.5 mm. long, cylindrical, rounded in front, tapering to a blunt point behind; pharynx somewhat in front of middle of body and just in front of genital pore: eastern states; Europe; abundant.

3. **Mesostoma** Ehrenberg. Excretory ducts open as in *Typhloplana;* rhabdites very prominent; testes dorsal or lateral to the yolk glands; genital pore in hinder third of body; mouth near the middle; 2 eyes present; *zoochlorellae* absent: 13 species, 2 American.

Fig. 261

Mesostoma ehrenbergi (Woodworth). 1, mouth 2, intestine.

M. ehrenbergi (Focke) (*M. wardii* Woodworth) (Fig. 261). Body flat, up to 15 mm. long and 4 mm. wide, but usually much less, tapering to both ends; forward end blunt, hinder end pointed: central states; Europe; viviparous.

Family 5. POLYCYSTIDIDAE.

Two ovaries, yolk glands, and testes present; forward end forms muscular retractile proboscis; rosette-shaped pharynx forward of the middle of body; but 1 genital pore: 16 species, 2 American.

Phonorhynchus von Graff. Male genital canal with a poisonous spine: 2 species.

P. helgolandicus (Metschnikoff). Length 1.7 mm.: Long Island and Vineyard Sounds to the Arctic Ocean; Europe; common.

Family 6. GYRATRICIDAE.

Ovaries, yolk glands, and a single testis present; forward end forms a retractile proboscis; mouth with a rosette-shaped pharynx near middle of body; genital pores separate, in hinder part of body: 1 genus.

Gyratrix Ehrenberg. With the characters of the family: 2 species.

G. hermaphroditus Ehr. Body 2 mm. long and very contractile, transparent: in fresh and salt water; eastern states; Europe; very common.

Suborder 2. ALLŒOCŒLA.

Fresh-water and marine turbellarians in which the intestine is an irregular sac or tube often with lateral diverticula; 1 or 2 genital pores present; testes and ovaries consist of numerous follicles: 7 families with about 75 species, 30 American.

Family PLAGIOSTOMIDAE.

Intestine sac-shaped and without lateral diverticula; pharynx variable and in forward part of the body; genital pore single and in hinder third of body; ovary and yolk glands distinct: 30 species, 10 American.

Fig. 262
Plagiostomum wilsoni
(von Graff).
1, mouth
2, intestine
3, genital pore.

Plagiostomum Schmidt. Two or 4 eyes present; pharynx large, sac-shaped: 10 American species; marine.

P. wilsoni von Graff (Fig. 262). Length 1.5 mm.: common at Woods Hole.

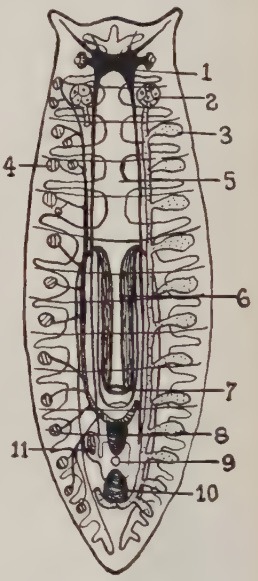

Fig. 263—Diagram of a triclad (von Graff). 1, brain; 2, ovary; 3, yolk gland; 4, testis; 5, intestine; 6, pharynx; 7, mouth; 8, penis; 9, genital pore; 10, vagina; 11, uterus.

Order 2. TRICLADIDA.

(Fig. 263.)

Marine, fresh-water, and terrestrial turbellarians in which the intestine is composed of 3 main trunks with many branches, one trunk extending forwards from the pharynx, and the other two backwards; body flattened, with sensitive lobes, projections or tentacles and a pair of eyes at or near the forward end, and in certain species a ventrally situated sucker; mouth and genital pore in or behind the middle of the body; proboscis well developed: about 430 species and 6 families grouped in 3 suborders.

Key to the suborders of *Tricladida:*

a_1 Aquatic triclads.
  b_1 Fresh-water triclads; planarians.....1. Paludicola
  b_2 Marine triclads.....2. Maricola
a_2 Terrestrial triclads.....3. Terricola

Suborder 1. PALUDICOLA.*

Planarians. Triclads with a central mouth, a single genital pore behind it and an elongate, flattened body, which are found in fresh water under stones and on plants, also in wet places under leaves, in mud, etc.; their food consists of crustaceans, snails, aquatic insects, etc., also of dead animals, and they are themselves preyed upon by fish, insect larvae, etc.; they possess remarkable regenerative powers and certain species (*Planaria maculata*) are known to multiply by fission; the eggs are laid in cocoons which are attached to stones and plants: 1 family and about 100 species, in fresh and often brackish water.

Family PLANARIIDAE.

With the characters of the suborder: about 6 genera.

Key to the genera of *Planariidae* here described:

a_1 But 1 pharynx present.
  b_1 Anterior margin rounded or angular.....1. Planaria
  b_2 Anterior end truncated.....2. Dendrocœlum
a_2 Many pharynges present.....3. Phagocata

1. Planaria O. F. Müller. Body elongate, flattened, rounded or angular forward, usually with a pair of lateral angular projections (auricles), and pointed behind; 2 eyes, each in a colorless area; usually a pair of lateral, elongated, and colorless sense spots near the eye: many species, about 9 American.

P. maculata† Leidy (Fig. 264). Body thin, slightly convex, elongate, tapering to the acute tail, 20 mm. long or less; head end trapezoidal, wider than the body, with an acute median and 2 lateral projections; mouth in hinder half; dorsal surface spotted irregularly with black; ventral surface whitish: North America; the commonest fresh-water planarian.

Fig. 264
Planaria maculata (Woodworth)
p, pharynx.

* See "Contributions to the Morphology of the Turbéllaria," etc., by W. M. Woodworth, Bull. Mus. Comp. Zool., Vol. 31, p. 1, 1897. "Regeneration in Planarians," by T. H. Morgan, Arch. f. Entwickelungsmech., Vol. 10, p. 58. "The Movements and Reactions of Fresh Water Planarians," by R. Pearl, Q. J. M. S., Vol. 46, p. 509, 1903. "The Reactions of Planarians to Light," by H. E. Walter, Jour. Ex. Zool., Vol. 5, p. 38, 1907. "Die Süsswasserfauna Deutschlands: Tricladida," by L. Böhmig, 1909.

† See "The Life History and Normal Fission of Planaria maculata," by W. C. Curtis, Proc. Bos. Soc. Nat. Hist., Vol. 30, p. 515, 1902.

P. torva M. Schultze (Fig. 265). Body 13 mm. long or less; head rounded in front and not wider than the body; color brown or black: eastern and central states; Europe.

P. gonocephala Dugès (Fig. 266). Body 25 mm. long or less; head

Fig. 265

Fig. 266

Fig. 267

Fig. 265—*Planaria torva* (Böhmig). Fig. 266—*Planaria gonocephala* (Woodworth). Fig. 267—*Planaria lugubris* (Böhmig).

as in *P. maculata;* body with parallel edges as far back as the genital pore; color brown or greenish: eastern states; Europe.

P. lugubris Schmidt (Fig. 267). Body 20 mm. long or less; head somewhat wider than body, rounded or bluntly triangular; color light brown to black; ductus ejaculatorius receives the secretion of numerous glands which appear on its inner surface: eastern and central states; Europe.

Fig. 268 Fig. 269

Fig. 268
Planaria dortocephala (Woodworth).

Fig. 269
Dendrocœlum graffi (Woodworth).

P. simplissima Curtis. Body 8 mm. long or less, black in color; head end blunt, without lateral projections; pigment wanting over eyes; testes few, 4 to 5 on a side: eastern states.

P. dortocephala Woodworth (Fig. 268). Body elongate, 15 mm. or more long, with acute angular front end and a pair of acute angular auricles; color brown: Illinois; common.

P. morgani Stevens and Boring. Body 10 mm. or more long, with a rounded or truncated front end, colorless: eastern states.

2. **Dendrocœlum** Œrsted. Body elongate and flat with a truncated head end which bears a large sucker and a pointed tail end; head set off by a slight constriction from the body and with a pair of short, rounded, lateral projections; mouth near the middle: several species.

D. graffi Wilhelmi (formerly called *D. lacteum* O. F. Müller) (Fig. 269). Body 10 to 26 mm. long and 3 mm. wide or less, milk white in color with the dark-colored intestine showing through; ventral sucker at front end; 2 eyes and frequently 1 to 6 accessory eye spots present: eastern states.

3. Phagocata Leidy. Body elongate and flat, with a rounded head end and a blunt tail end; many pharynges present which lie in a common chamber and when extruded reach the exterior through a single orifice, but which open separately into the intestine: 1 species.

P. gracilis* (Haldeman) (Fig. 270). Body 30 mm. long and 4.5 mm. wide or less, black in color; 1 large pharynx present at the junction of the 3 main intestinal trunks and about 22 additional pharynges which are joined to the 2 lateral trunks: eastern states, often plentiful in brackish water.

Fig. 270
Phagocata gracilis (Woodworth).
1, pharynges
2, intestine.

Suborder 2. MARICOLA.†

Marine triclads. Intestinal branches but little ramified; mouth in hinder half of body; uterus behind genital pore: 5 families and about 30 species, which live on seaweed, stones, or shells, or are parasitic; 10 species on east coast of America.

Family 1. PROCERODIDAE.

Body flattened, with otocyst but no sense pits; front end more or less truncate, often with a pair of tentacle-like projections; 2 eyes, at some distance from front end: 2 genera.

Procerodes Girard (*Gunda* O. Schmidt). Body elongate, truncated in front with projecting, tentacle-like corners: 16 species.

Fig. 271
Procerodes wheatlandi (Verrill).

P. wheatlandi Girard (Fig. 271). Body elongate, 5 mm. long and 1 mm. wide, blackish in color; tentacles whitish: coast of New England, often common under stones and among algae in shallow water; Europe.

P. warreni (Girard). Front end more or less truncate; body elongate, yellowish or brownish in color, 4 to 12 mm. long, and 2 to 3 mm. wide: New England coast; not common.

Family 2. BDELLOURIDAE.‡

Body elongate and flattened and colorless; 2 eyes present; rhabdites absent; 2 uteri present with independent openings to the outside;

* See "Contributions to the Morphology of the Turbellaria," by W. M. Wood worth, Bull. Mus. Comp. Zool., Vol. 21, p. 1, 1891.

† See "Marine Planarians of the New England Coast," by A. E. Verrill, Trans. Conn. Acad., Vol. 8, 1893. "Tricladensstudien I. Tricladida maricola," by L. Böhmig, Zeit. f. wiss. Zool., Vol. 81, p. 344, 1906. "On the N. A. Marine Triclads," by J. Wilhelmi, Biol. Bull., Vol. 15, p. 1, 1908. "Tricladen," by same, Die Fauna u. Flora d. Golfes v. Neapel, 1909.

‡ See "Syncœlidium pellucidum," etc., by W. M. Wheeler, Jour. Morph., Vol. 9, p. 167, 1894.

egg capsules attached by a slender pedicle: 2 genera and 4 species, parasitic or commensal on the gills and outer surface of *Limulus polyphemus.*

1. Bdelloura Leidy. Anterior end tapering; posterior end wide, with a glandular disc for attachment: 3 species.

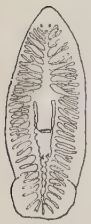

Fig. 272
Bdelloura candida (Verrill).

B. candida (Girard) (Fig. 272). Body 15 mm. long, 4 mm. wide, gray in color; egg capsule 2.5 to 4 mm. long; testicular sacs 60 to 100 in number: often very common.

B. propinqua Wheeler. Body 8 mm. long; testicular sacs about 170 in number; egg capsule 1.25 mm. long; not so common as the above.

B. wheeleri Wilhelmi. Body 6 mm. long, 1 mm. wide, the greatest width being in front of the pharynx; sucker not set off from body: on *Limulus;* not common.

2. Syncœlidium Wheeler. Body elongate, tapering towards both ends, which are blunt; posterior rami of intestine unite, forming a single median trunk: 1 species.

S. pellucidum Wheeler (Fig. 273). Body 3 mm. long; testicular follicles large, about 14 on each side of the body; egg capsules .75 mm. long.

Fig. 273
Syncœlidium pellucidum (Wheeler).

Suborder 3. TERRICOLA.*

Land planarians. Intestinal branches simply lobed; position of mouth variable; uterus small, behind the genital pore; body oval or elongate, and usually brightly colored, and with a creeping sole on the ventral surface: 5 families and about 400 species which occur mostly in tropical countries, living in damp places.

Fig. 274
Placocephalus kewensis (von Graff).

Family 1. BIPALIIDAE.

Body often very elongate, usually brightly colored, and with longitudinal or transverse stripes; head end broadened, forming plate with numerous marginal eyes; mouth median or post-median; genital pore back of mouth: 4 genera and about 90 species.

Placocephalus von Graff. Body often enormously elongate; head plate thin, much broader than long, and with a semicircular margin: 15 species.

P. kewensis (Mosley) (Fig. 274). Body 10 to 20 cm. (in some cases 45 cm.) long, narrow and with parallel sides, yellowish in color; with 7 longitudinal stripes; sole white: greenhouses in America and Europe; native country unknown, although possibly Samoa.

* See "Monographie d. Turbellarien, II. Tricladida terricola," by L. von Graff, Leipzig, 1899.

Family 2. RHYNCHODEMIDAE.

Body elongate, with more or less parallel sides; head not distinct, with 2 spherical eyes near the front end; mouth near the middle: 7 genera and about 100 species.

Rhynchodemus Leidy. Head end very contractile and often extended like a proboscis; body more or less cylindrical; eyes small: 35 species.

R. sylvaticus Leidy. Body somewhat fusiform, thick, convex above and flattened below, 10 mm. long, 3 mm. thick and 1 mm. wide; forward end narrowed and very extensile; color gray with two longitudinal stripes on the back and a transverse spot near the middle: eastern states, in woody places.

Order 3. POLYCLADIDA.*

Marine turbellarians, often of large size, with thin, leaf-like body; intestine with very numerous branches which ramify to all parts of the body; eyes numerous; otocysts, tentacles and stiff tactile cilia also often present; no yolk glands; 2 genital pores; mouth central or posterior; no asexual reproduction: 225 species grouped in 2 suborders.

Key to the suborders of *Polycladida:*

a_1 No suckers present.....1. Acotylea
a_2 A ventral sucker present.....2. Cotylea

Suborder 1. ACOTYLEA.

Polyclads without a sucker; genital pores near hinder end of body: 3 families.

Key to the suborders of *Polycladida:*

a_1 Two dorsal tentacles present.....1. Planoceridae
a_2 No tentacles present.....2. Leptoplanidae

Family 1. PLANOCERIDAE.

Two dorsal tentacles, usually containing ocelli; mouth central; copulatory apparatus directed backwards; marginal and cerebral eyes present or absent: about 8 genera and 45 species.

1. Planocera Blainville. Body oval or elliptical and flattened; tentacles slender, situated at some distance from front end of body with a cluster of eyes at the base of each; cerebral ocelli inconspicuous; genital pores separate but near together: about 25 species.

P. nebulosa Girard. Body convex and rather thick, 29 mm. long and 10 mm. wide, and usually olive green in color with a median dorsal stripe; mouth central: Charleston to Cape Cod, under stones.

* See "Die Polycladien des Golfes von Neapel," etc., by A. Lang, Fauna u. Flora d. Golfes v. Neapel, xi Monographie, 1884.

P. inquilina Wheeler (Fig. 275). Body oval, 6 mm. long and 4 mm. wide; edges remain in contact with the surface over which the animal is moving; color grayish: Vineyard Sound, mantle cavity of *Fulgur*.

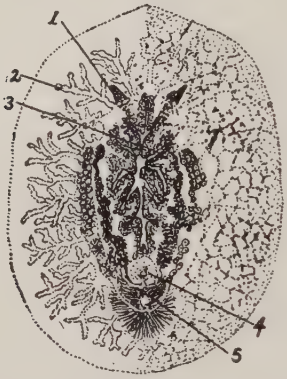

Fig. 275

Fig. 276

Fig. 275—*Planocera inquilina* (Wheeler). 1, tentacle; 2, intestine; 3, mouth; 4, male genital pore; 5, female genital pore. Fig. 276—*Stylochus ellipticus* (Verrill). 1, tentacle; 2, mouth.

2. Stylochus Ehrenberg. Body oval or elliptical and flat; tentacles short; pharynx with several accessory lobes; genital pores near hinder end of body: 10 species.

S. ellipticus (Girard) (Fig. 276). Body flat and thin with undulating margins, 20 mm. long and 6 mm. wide, yellowish-brown in color, irregularly radially veined; tentacles small, white, each with a cluster of ocelli; 8 to 12 frontal and cerebral and numerous marginal ocelli present: New England coast, the commonest of the larger marine planarians, especially south of Cape Cod.

Fig. 277
Leptoplana variabilis (Verrill).

Family 2. LEPTOPLANIDAE.

Body broad, flat, thin, without tentacles; mouth central; pharynx lobed; usually 4 groups of ocelli, 2 cerebral and 2 dorsal; marginal ocelli sometimes present; male copulatory apparatus directed backwards: 4 genera and about 60 species.

Leptoplana Ehrenberg. Body foliaceous with undulating edges; no marginal ocelli; genital pores rather widely separated, the male pore being distant from the end of the body: 25 species.

L. variabilis (Girard) (Fig. 277). Body elliptical, 18 mm. long and 8 mm. wide, yellowish-brown in color; ocelli conspicuous, the cerebral clusters containing about 30 each and the dorsal clusters about 15: New England coast, often abundant.

L. folium Verrill. Body very changeable, 25 mm. long and 15 mm. wide, yellowish or pink in color; ocelli very numerous, small, and inconspicuous: New England coast.

Suborder 2. COTYLEA.

Polyclads with a sucker in the ventral surface behind the genital pores: 4 families with about 110 species.

Family PROSTHIOSTOMIDAE.

Body elongate and without tentacles; cerebral ocelli on the anterior margin of the body; mouth immediately behind brain; pharynx long and tubular: 1 genus.

Prosthiostomum Quatrefages. With the characters of the family: 8 species.

P. gracile Girard. Body thin and translucent, yellowish-white in color, 4 mm. long and 1.25 mm. wide; ocelli in 4 groups: New England coast; not common.

Class 2. TREMATODES.*

The flukes. Soft, flat or round worms which live as parasites on the skin or gills of fishes and other aquatic animals or in the internal organs of vertebrates and also of many invertebrates. The smallest are of microscopic size, the largest may be a number of centimeters in length. The outer surface of the adult body is an unciliated cuticula in which suckers and chitinous hooks or spines are present, which enable the animal to fix itself to its host. No body cavity is present, the spaces between the organs being filled with the vesicular parenchyma.

The mouth is at the forward end of the body (except in *Bucephalus*). The intestine is, with a few exceptions, bifurcate and is without anal opening: the food consists of the blood and other juices of the host. The excretory system consists of two main portions, the excretory vesicles and the excretory tubules. The latter ramify throughout the parenchyma and end with flame cells. The former consist of a pair of lateral canals which receive the tubules and open to the outside through a pair of anterior pores in the *Monogenea* and a median posterior pore in the *Digenea*. The nervous system consists of a pair of ganglia just back of the mouth which are joined with each other by a commissure and of nerves which pass to

* See "Plathelminthes, I. Trematodes," by M. Braun, Bronn's Klassen, etc., Bd. 4, p. 306, 1892. "Die thierischen Parasiten des Menschen," by same, 1903. "Illustrated Key to the Trematode Parasites of Man," by C. W. Stiles, Bull. No 17, Hyg. Lab., Treas. Dept., 1904. "Index Catalogue," etc., "Trematoda," by same, Bull. No. 37, same, 1908. "Trematodes," by M. Lühe, Die Süsswasserfauna Deutschl., 1910.

the various organs. Several pairs of large longitudinal nerves pass to the hinder part of the body.

With a few exceptions all trematodes are hermaphroditic, the male and female pores being either confluent, in which case a genital atrium is often present, or side by side and near together in the ventral surface. The arrangement of the genital organs is complex and varies somewhat in the three orders of trematodes. The egg is composite in structure, consisting of an ovum and several yolk cells.

Habits and Distribution.—The young trematode leads a free life for a short time and then seeks its host. The most primitive trematodes are external parasites and the entire life may be passed on a single host. The higher forms, on the other hand, are internal parasites and live in two or more hosts, the adult host being different from the larval host, and the passage from one host to the other being accompanied by a metamorphosis. The former are called monogenetic and the latter digenetic trematodes. Many of the latter are dangerous parasites to man and his domestic animals.

History.—This class was established in 1808 by Rudolphi, who included in it the genera, *Monostoma* Zeder, *Amphistoma* Rudolphi, *Distoma* Retzius, and *Polystoma* Zeder. It was not until 1858 that the distinction between the ectoparasitic and the entoparasitic forms found expression in the classification, when P. J. van Beneden formed the groups *Monogenea* to include the former and the *Digenea* for the latter. In 1892 Monticelli showed the need of subdividing the *Digenea* and established the following suborders: the *Heterocotylea,* the *Aspidocotylea,* and the *Malacocotylea,* the first of which coincides with the *Monogenea.* This subdivision was generally adopted, but is now being abandoned in favor of the simpler one of van Beneden. The explanation of the complex metamorphosis of trematodes was first given by Steenstrup in 1842. Thomas and Leuckart discovered almost simultaneously in 1881 the life history of the common liver fluke (*Fasciola hepatica*), and the latter author and Looss have played the principal part in the investigation of the entire group.

About 2,500 species of trematodes are known, which may be grouped in 3 orders.

Key to the orders of *Trematodes:*

a_1 Ectoparasitic trematodes (except *Polystoma*) ; hooks usually present in the suckers or sucking discs.....1. MONOGENEA

a_2 Mostly entoparasitic trematodes; no hooks in the suckers or sucking discs.

b_1 Either a large ventral sucking disc or a midventral row of suckers; no oral sucker.....2. ASPIDOCOTYLEA

b_2 Usually either 1 or 2 median suckers; oral sucker present (except in *Bucephalus*).....3. DIGENEA

Order 1. MONOGENEA.*

Monogenetic trematodes (Fig. 278). Usually external parasites on fish and other aquatic animals. Most forms live on but a single host and are found most often on the gills, being that part of a fish's body where the blood is nearest the surface and where a parasite is also protected; some, however, live in the mouth and some in the cloaca. The genus *Polystoma* is entoparasitic. The organs of attachment are at the extremities of the body. At the hinder end is a large disc more or less sharply set off with either suckers or hooks, or both these organs. At the forward end is usually a pair of suckers with the mouth between them. These may, however, be absent or their place may be taken by a single oral sucker, by paired glands, or by tentacle-like structures. The order contains 4 families and about 500 species.

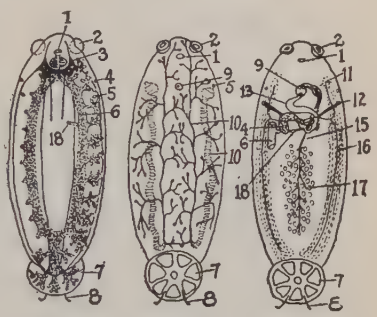

Fig. 278—Diagram of a monogenetic trematode (Benham). 1, mouth; 2, anterior sucker; 3, brain; 4, vagina; 5, excretory pore; 6, intestine; 7, posterior sucking disc; 8, hook; 9, genital pore; 10, excretory canal; 11, penis; 12, vagina; 13, uterus; 14, ovary; 15, sperm duct; 16, yolk glands; 17, testes; 18, genito-intestinal canal.

Key to the families of *Monogenea:*

a_1 Large posterior sucking disc without suckers or marginal hooks.
b_1 A pair of anterior suckers or sucker-like projections with mouth between. 1. Tristomidae
b_2 A single anterior sucker, or none.....2. Monocotylidae
a_2 Disc-like posterior region with either paired suckers or marginal hooks.
b_1 Posterior region with suckers.....3. Polystomidae
b_2 Posterior region without suckers.....4. Gyrodactylidae

Family 1. TRISTOMIDAE.

Mostly broad, flat worms, with a pair of anterior suckers or sucker-like membranes, one on either side of the mouth, and a large posterior sucking disc in which hooks are often located, the anterior suckers being without hooks; a pair of eye spots often present; intestine bifurcate and often much branched; genital pores near the forward end, the male and female openings being in some cases separated from each other: on the skin or gills of marine fishes or in the mouth or cloaca; about 11 genera.

* "Notes on Trematode Parasites of Fishes," by E. Linton, Proc. U. S. Nat. Mus., Vol. 20, p. 507, 1898. "Notes on Some Exotic Species of Ectoparasitic Trematodes," by S. Goto, Jour. Sci. Coll., Imp. Univ., Vol. 12, p. 263, 1899. "Synopsis of the Trematodes, Part I. The Heterocotylea," by H. S. Pratt, Am. Nat., Vol. 34, p. 645, 1900. "Fish Parasites of the Woods Hole Region," by E. Linton, Bull. Fish. Com., Vol. 19, p. 405, 1901.

Key to the genera of *Tristomidae* here described:

a_1 Sucking disc not set off from body and with 7 radial ridges...1. TRISTOMA

a_2 Sucking disc set off from body and without radial ridges.

b_1 Body elongate; sucking disc terminal with many minute hooks. 2. NITZSCHIA

b_2 Body elliptical; sucking disc ventral with large hooks.....3. EPIBDELLA

1. TRISTOMA Cuvier. Body very flat, circular, or oval, with a pair of anterior suckers and a large ventral sucking disc in which are 7 radial ridges and small hooks; intestine with side branches; genital pores near the margin of the body; many testes present: about 10 species.

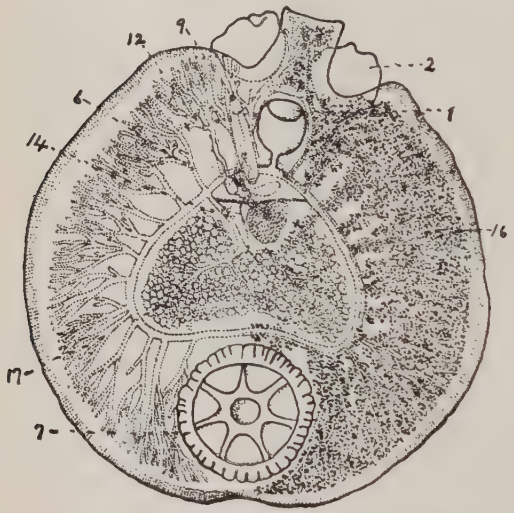

Fig. 279—*Tristoma coccineum* (from Bronn). References as in Fig. 278.

T. coccineum Cuv. (Fig. 279). Body about 15 mm. long and 16 mm. wide and red in color: on the gills of the swordfish.

2. NITZSCHIA von Baer. Body elongate, with sucking disc terminal and without radii; 2 large suckers at forward end; numerous testes: 1 species, in salt and fresh water.

N. sturionis (Abildgaard) (Fig. 280). Body reddish, 16 mm. long, 5 mm. wide; sucking disc globose: on gills of the sturgeon.

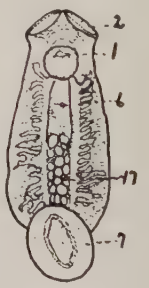

Fig. 280 *Nitzschia sturionis* (Monticelli). References as in Fig. 278.

3. EPIBDELLA Blainville. Body elliptical and flat; sucking disc ventral without ridges, but often with papillae; 4 small eyes; 2 testes: several species.

E. bumpusi Linton (Fig. 281). Length 12 mm.; width 8 mm.: on skin of *Dasyatis centrura;* Woods Hole.

FAMILY 2. MONOCOTYLIDAE.

Flat and circular or elliptical worms without paired anterior suckers and with a single posterior sucking plate, which is sometimes very small: on the skin, gills, or in the cloaca of marine fishes; 7 genera.

MONOCOTYLE Taschenberg. Sucking disc with 8 radial ridges; 1 to 3 testes: on the skin or gills of skates.

M. floridana Pratt (Fig. 282). Body 1.3 mm. long and .58 mm. wide; oral sucker present; intestinal branches joined at hinder end and prolonged in a median cœcum: on the gills of *Myliobatis freminvillei.*

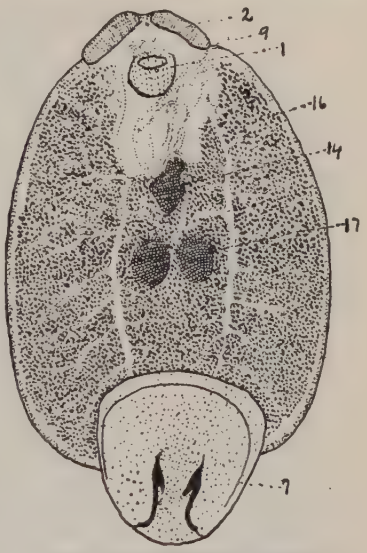

Fig. 281—*Epibdella bumpusi* (Linton). References as in Fig. 278.

Family 3. POLYSTOMIDAE.

Body flat and broad, with a more or less distinct disc or region at the hinder end bearing suckers, usually paired, the number of which may vary from 2 to 120, and also in most cases hooks; anterior suckers either present or not: on gills of fishes and in the mouth, nose, and urinary bladder of amphibians and reptiles; about 21 genera and 3 subfamilies.

Key to the subfamilies of *Polystomidae:*

a_1 Anterior suckers absent; either 2 or 6 posterior suckers. 1. Polystominae
a_2 Anterior suckers present.
  b_1 Posterior suckers 4 to 8. . . . . 2. Octocotylinae
  b_2 Posterior suckers very numerous. . . . . 3. Microcotylinae

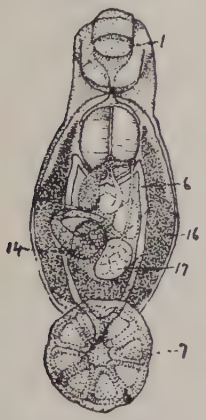

Fig. 282 *Monocotyle floridana* (Pratt). References as in Fig. 278.

Subfamily 1. POLYSTOMINAE.

Posterior sucking disc distinctly set off and with 2 or 6 large suckers arranged in pairs and also 2 or more large hooks; paired anterior suckers absent: about 5 genera.

1. Polystoma Zeder. Body without anterior and with 3 pairs of posterior suckers; vagina paired with an opening on either margin of the anterior portion of the body: on the gills of frog tadpoles as larvae, and in the urinary bladder of amphibians and in the mouth, nose, and urinary bladder of turtles as adults; 6 species, 3 in America.

P. oblongum R. R. Wright. Disc attached at its anterior end; intestine with no side branches; body elliptical; cirrus with 16 spines, alternately large and small; length 2.5 mm.; width 1 mm.: in urinary bladder of musk, painted, and snapping turtles.

P. coronatum Leidy. Body lanceolate, 6 mm. long, with 3 pairs of minute hooks between the anterior pair of suckers, and 1 large and 2 small pairs between the posterior pair: in the nose of the food terrapin.

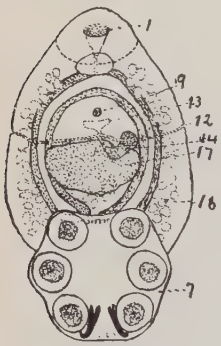

Fig. 283—*Polystoma hassalli* (Goto). References as in Fig. 278.

P. hassalli Goto (Fig. 283). Body ovate; 1.5 mm. long and 1 mm. wide; disc hexagonal with 3 pairs of small hooks between the anterior pair and 1 pair of large hooks between the posterior pair of suckers; intestine without side branches: in the urinary bladder of *Kinosternum pennsylvanicum*.

2. Sphyranura Wright and MacCallum. Body elongate with a small posterior disc containing 2 large suckers: 2 species.

S. osleri Wr. and MacC. (Fig. 284). Body tapering at both ends, 4 mm. long and .6 mm. wide; disc wider than body; testes numerous: on skin and gills of *Necturus maculatus*.

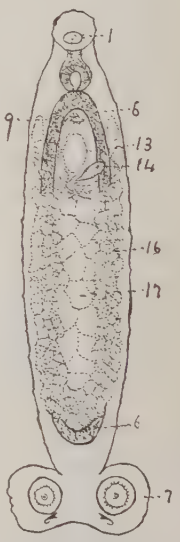

Fig. 284 *Sphyranura osleri* (Wright and MacCallum). References as in Fig. 278.

Subfamily 2. OCTOCOTYLINAE.

Posterior region with 8 (4) large suckers; paired anterior suckers present: about 12 genera.

Key to the genera of *Octocotylinae* here described:

a_1 Posterior disc-like region with median hooks.....1. Discocotyle

a_2 Median hooks not present. 2. Diclidophora

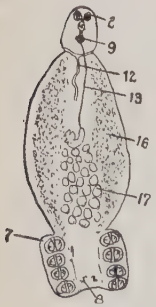

Fig. 285 *Discocotyle salmonis* (Shaffer). References as in Fig. 278.

1. Discocotyle Diesing. Body elongate with small hooks in the posterior disc; posterior suckers slightly stalked and with strong chitinous support; vagina Y-shaped: several species.

D. salmonis Shaffer (Fig. 285). Body lanceolate; posterior suckers slightly raised and with 1 pair of hooks; 5 mm. long: on the gills of the rainbow trout.

2. Diclidophora Goto. Body elongate; posterior suckers either stalked or not and acting as pincers; each sucker with a chitinous frame work in form of a Greek cross: on the gills of the *Sparidae* and other marine fishes.

D. affinis (Linton). Body attenuate, spatulate; anterior portion elliptical; posterior portion cylindrical; posterior suckers with long stalks; length 12 to 40 mm.: in the mouth of the flounder.

Subfamily 3. MICROCOTYLINAE.

Paired anterior suckers present; posterior disc-like region elongate and bearing numerous small suckers, which may be found only on one side, making the animal asymmetrical: 4 genera.

Microcotyle van Beneden and Hesse. Posterior region bearing 10 to 120 pairs of minute sessile suckers: on gills of marine fishes; many species.

M. longicauda Goto. Sucker disc more than half the length of the body; about 120 pairs of suckers present; 7 mm. long; 2 mm. wide: on the gills of the weakfish; Newport.

M. pogoniae MacCallum (Fig. 286). Sucker disc about a third of the body; length 12 mm.: on *Pogonias cromis,* often very numerous.

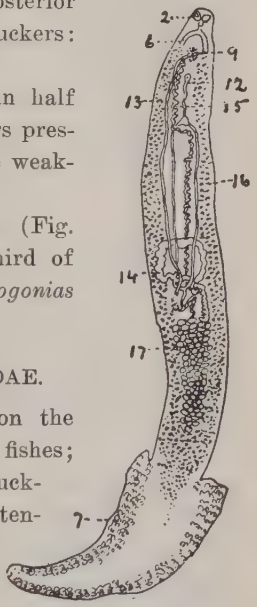

Fig. 286—*Microcotyle pogoniae* (MacCallum). References as in Fig. 278.

Family 4. GYRODACTYLIDAE.

Minute forms occurring on the gills of fresh-water and marine fishes; body minute, usually without suckers, but with 2 to 4 retractile tentacles at the forward end and a disc at the hinder end armed with numerous hooks: about 9 genera. In the genus *Gyrodactylus* a curious pædogenesis often occurs. A young individual will come to sexual maturity before it is born and while it is still in the maternal uterus, and produce young in its uterus. This last individual may also have young in its uterus, and 4 generations may thus be found, one inside of another.

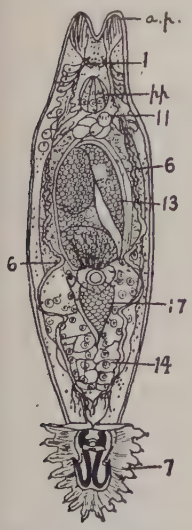

Fig. 287—*Gyrodactylus elegans* (from Bronn). a.p., anterior projection; p.p., pharynx. Other references as in Fig. 278.

Gyrodactylus Nordmann. Minute, elongated worms with 2 short anterior projections and a posterior disc bearing about 16 marginal hooks and 2 large central ones; no eyes present: 4 species.

G. elegans Nordmann (Fig. 287). Length 1 mm.; width .2 mm.: on the gills and skin of the carp and other fresh-water fishes.

Order 2. **ASPIDOCOTYLEA.** (Fig. 288.)

Monogenetic and digenetic trematodes which attach themselves to their host by means either of a median row of suckers or a very large ventral sucking disc in which are sucking pits or depressions and on the margin of which are often sense organs; hooks and anterior suckers not present and intestine not bifurcate: in the intestine of fishes and reptiles and in mollusks and crustaceans; 1 family and a small number of species.

Fig. 288
Diagram of the *Aspidocotylea* (*Aspidogaster*) (after Benham).
1, mouth
2, intestine
3, genital pore
4, ovary
5, yolk glands
6, uterus
7, testis
8, ventral suckers or sucking disc.

Family ASPIDOBOTHRIDAE.

With the characters of the order: 8 genera.

Key to the American genera of *Aspidobothridae:*

a_1 Body cylindrical with a midventral row of suckers. 1. Stichocotyle

a_2 Large ventral sucking disc containing 3 or 4 longitudinal rows of depressions.

b_1 Three rows present.

c_1 Median depressions very elongate transversely, the lateral depressions being round.....2. Cotylogaster

c_2 All the depressions transversely elongate.3. Cotylaspis

b_2 Four rows present.....4. Aspidogaster

1. Stichocotyle Cunningham. Body cylindrical and elongate with a midventral row of 20 to 30 suckers extending the length of the body: 1 species.

S. nephropis* Cunn. (Fig. 289). Length of adult 17 to 105 mm., with 20 to 27 suckers; length of the larva 3 to 7 mm., with 7 to 22 suckers: adult lives in the liver of *Raja* and the larva encysted in the intestinal walls of lobsters and large crabs on the Atlantic coast; Europe.

Fig. 289
Stichocotyle nephropis; a larva from a lobster (Nickerson). References as in Fig. 288.

2. Cotylogaster Monticelli. Sucking disc long and narrow with 2 lateral rows of round depressions and a median row of very elongate transverse depressions; 2 testes; marginal sense organs: 2 species, in the intestine of marine and fresh-water fishes.

C. occidentalis† Nickerson (Fig. 290). Sucking disc with 132 to 144 depressions; length 10 mm.: in the sheepshead in Minnesota.

* See "Ueber die geschlechtsreife Form von Stichocotyle nephropis Cunn.," by T. Odhner, Zool. Anz., Vol. 21, p. 500, 1898.

† "Cotylogaster occidentalis n. sp. and a Revision of the Family Aspidobothridae," by W. S. Nickerson, Zool. Jahrb. Abt. f. Sys., Vol. 15, p. 697, 1902. "Synopsis of the Trematodes, Part II. The Aspidocotylea," etc., by H. S. Pratt, Am. Nat., Vol. 36, p. 887, 1902.

3. Cotylaspis Leidy. Sucking disc broadly elliptical with 3 rows of transversely elongated depressions; marginal sense organs and 2 eyes present: in the mantle cavity of mussels and the intestine of turtles; 2 species.

Fig. 290 *Cotylogaster occidentalis* (Nickerson). References as in Fig. 288.

C. insignis* Leidy (Fig. 291). Length 1.8 mm.; number of depressions about 29: on the kidney of *Anodonta;* common.

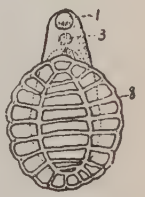

Fig. 291 *Cotylaspis insignis* (Osborn). References as in Fig. 288.

4. Aspidogaster von Baer. Small worms in which the body consists of a cylindrical anterior portion and a very large elliptical ventral disc in which are 4 longitudinal rows of sucking depressions, numbering 64 to 120 and with marginal sense organs; 1 testis: in the intestines of fishes and in fresh-water pelecypods and marine gastropods; several species.

A. conchicola v. Br. (Fig. 292). Body elongate; number of depressions about 64; length 3 mm.; 34 marginal sense organs: mostly in the liver, pericardium, and kidney of *Unio* and *Anodonta;* Europe.

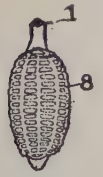

Fig. 292 *Aspidogaster conchicola* (Monticelli). References as in Fig. 288.

Order 3. DIGENEA.† (Fig. 293.)

Entoparasitic, digenetic trematodes living in two or more hosts, to which they attach themselves by means of either one or two median suckers. One of these is always an oral sucker and at the front end of the body, except in *Bucephalus;* the second sucker, when present, is either on the ventral surface or at the hinder end of the body and is called the acetabulum. A few blood-infesting forms are without suckers. In the *Holostomidae* an additional organ of attachment in form of a large disc or projection back of the acetabulum is also present. Hooks are never present in connection with the suckers but in some cases with the genital organs, and the body is often covered with small spines. The median

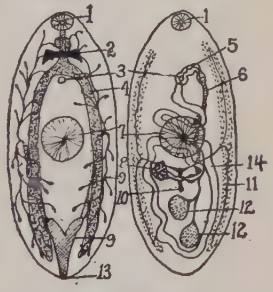

Fig. 293—Diagram of a *digenetic trematode* (Benham, altered). 1, oral sucker; 2, brain; 3, genital pore; 4, intestine; 5, cirrus; 6, receptaculum seminis; 7, acetabulum; 8, ovary; 9, excretory canal; 10, Laurer's canal; 11, yolk glands; 12, testis; 13, excretory pore; 14, uterus.

* See "On the Habits and Structure of Cotylaspis insignis," etc., by H. L. Osborn, Zool. Jahrb. Abt. f. Anat., Vol. 21, p. 201.

† See "Synopsis of the Trematodes, Part II. The Aspidocotylea and the Malacocotylea," etc., by H. S. Pratt, Am. Nat., Vol. 36, p. 887, 1902.

excretory pore is at the hinder end of the body and the genital pore is in the ventral surface or on the margin of the body. Special sense organs are with rare exceptions absent. The life history is known of but very few trematodes. The young animal passes out of the host in the egg, on leaving which it is usually a ciliated larva called the miracidium; this larva seeks an intermediate host, often a mollusk, in the body of which it passes its larval life, living actively or encysted in some of the compact tissues. It here passes through one or more metamorphic stages which finally result in the production of young individuals, called cercariae, each of which has usually a locomotive tail (in *Bucephalus* two) (Fig. 294), which sometimes seek still another intermediate host, and are destined to develop into the adult worms. If, now, the host harboring these larval worms be devoured by the final host, the young worms pass into the intestine or some other hollow organ of the latter and become mature. Tailless cercariae, which are quite numerous, do not leave the first intermediate host, but pass directly with it into the final host. Digenetic trematodes are common parasites, the adult worms being found in almost all vertebrate animals. The larval worms are usually found in snails, small fish, and other small animals. Some of them are dangerous parasites to man and his domestic animals. The order contains about 2,000 species, grouped in 2 suborders.

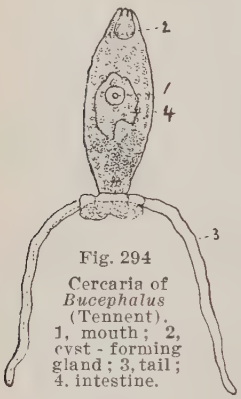

Fig. 294
Cercaria of *Bucephalus* (Tennent). 1, mouth; 2, cyst-forming gland; 3, tail; 4, intestine.

Key to the suborders of *Digenea:*

a_1 Mouth median in position.....1. GASTEROSTOMATA
a_2 Mouth anterior in position.....2. PROSTOMATA

SUBORDER 1. GASTEROSTOMATA.

Mouth in the middle of the ventral surface; intestine sac-like and not bifurcate: 1 family.

FAMILY BUCEPHALIDAE.

But one sucker present which is at the front end of the body; mouth in the middle of the ventral surface; intestine sac-like and not bifurcate; genital pore at hinder end: in intestine of fish, in both fresh and salt water; the larval forms in bivalve mollusks; 2 genera.

BUCEPHALUS von Baer (*Gasterostomum* von Siebold). Yolk glands in two distinct groups of follicles; male genital pore at end of a papilla: numerous species.

B. gracilescens (Rudolphi) (Fig. 295). Length 1.4 mm.; width .5 mm.: in *Tylosurus marinus* and other marine fishes; larva (Fig. 294) in gonads and other organs of the oyster, often causing death.

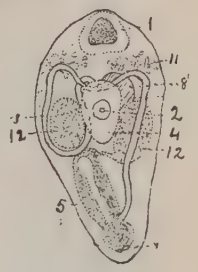

Fig. 295 *Bucephalus gracilescens* (Tennent). 1, sucker; 2, mouth. Other references as in Fig. 293.

Suborder 2. PROSTOMATA.

Mouth at the anterior end, in the oral sucker; intestine bifurcate (with a few exceptions): 4 divisions.

Key to the divisions of *Prostomata:*

a_1 But 1 sucker present.....1. Monostomata
a_2 Two suckers present.
b_1 Acetabulum at hinder end.....2. Amphistomata
b_2 Acetabulum in ventral surface.
c_1 Additional organs of attachment not present. 3. Distomata
c_2 Additional sucking disc or projection present. 4. Holostomata

Division 1. MONOSTOMATA.

Oral sucker alone present; arrangement of organs similar to that of the *Distomata:* in vertebrates, especially birds and sea turtles; several families.

Fig. 296—*Pronocephalus renicapitis* (Braun). References as in Fig. 293.

Family 1. CYCLOCŒLIDAE.

Large trematodes in which the intestinal trunks join at the hinder end; genital pore in anterior half of the body; ovary in front of testes: in the air passages of birds; 6 genera.

Cyclocœlum Brandes. Intestinal trunks without lateral branches; uterus entirely between the trunks: 10 species.

C. mutabile (Zeder). Body elongate, attenuate forward and about 18 mm. long; testes small, the hinder one near the juncture of the intestinal trunks: in *Gallinago* and other birds.

Family 2. PRONOCEPHALIDAE.

Body usually elongate, with a collar-like rim around the head; testes and ovary in hinder end of body, the testes being in same transverse plane with the intestinal trunks between them: in turtles.

Pronocephalus Looss. With the characters of the family: several species.

P. renicapitis (Leidy) (Fig. 296). Length 25 mm.; width 3 mm.; testes lobate: intestine of *Sphargis coriacea.*

Division 2. AMPHISTOMATA.

Body often more or less conical, with the oral sucker at the front end and the acetabulum at the hind end of the body; intestine bifurcate, the pharynx often having a pair of lateral pockets; testes 1 or 2 in number, large, and situated in front of the small ovary; yolk glands usually large; genital pore in the forward part of body: in all classes of vertebrates, usually in the digestive tract; 3 families.

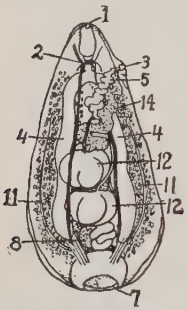

Fig. 297—*Paramphistomum cervi* (from Braun).

Family PARAMPHISTOMIDAE.

With the characters of the division: 8 genera.

1. Paramphistomum Fischöder. Oral sucker rudimentary; acetabulum large, with the excretory pore just dorsal to it; no pharyngeal pockets: in the stomach and intestine of vertebrates, principally mammals; about 25 species.

P. cervi (Zeder) (*P. conicum* Zed.) (Fig. 297). Body conical, 10 mm. long: in stomach of sheep and cattle; rare in this country.

2. Diplodiscus Diesing. Acetabulum large, with the excretory pore in its center; pharyngeal pockets present: in rectum of amphibians; several species.

D. temporatus* Stafford (Fig. 298). Body conical; about 3.6 mm. long: in rectum of frogs; not uncommon.

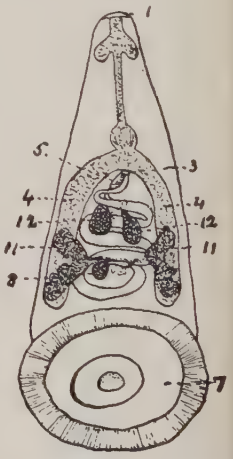

Fig. 298—*Diplodiscus temporatus* (Cary). References as in Fig. 293.

Division 3. DISTOMATA.†

Body flattened or cylindrical and often covered with minute spines, with the oral sucker at the front end and the acetabulum in the ventral surface; intestine, with a few exceptions, bifurcate, the 2 trunks being either short or long and branched or simple; usually a pair of testes (in a few species several pairs); a single ovary, which is smaller than either testis, and often a large receptaculum

* See "The Life History of Diplodiscus temporatus," etc., by L. R. Cary, Zool. Jahrb. Abt. f. Anat., Vol. 28, p. 595, 1909.

† See "An Inventory of the Genera and Subgenera of the Trematode Family Fasciolidae," by C. W. Stiles and A. Hassall, Arch. de Paras., Vol. 1, p. 81, 1898. "Weitere Beiträge zur Kenntniss der Trematoden Fauna Ægyptens," etc., by A. Looss, Zool. Jahrb. Abt. f. Sys., Bd. 12, p. 521. "Nachträgliche Bemerkungen," etc., by A. Looss, Zool. Anz., Bd. 23, p. 601, 1900.

seminis present; the uterus is a long tube, containing eggs; yolk glands either branched or compact: parasitic as adults in the intestine and other hollow organs of vertebrates; over 1,700 species, the family relationships of which are as yet more or less obscure.

Key to the genera of *Distomata* here described:

a_1 Hermaphroditic distomes.
b_1 Ovary in front of testes.
c_1 Uterus does not extend back of testes.
d_1 Intestinal trunks with lateral projections; ovary and testes branched. 1. Fasciola
d_2 Intestinal trunks without lateral projections.
e_1 Genital pore back of acetabulum ..... 2. Paragonimus
e_2 Genital pore not back of acetabulum.
f_1 Mouth surrounded by spines.
g_1 A single row of spines ..... 3. Echinostoma
g_2 A double row of spines ..... 4. Stephanochasmus
f_2 No spines around the mouth.
g_1 Excretory vesicle winds between the testes ..... 5. Amphimerus
g_2 Excretory vesicle does not wind thus ..... 6. Azygia
c_2 Uterus extends back of testes.
d_1 Mouth surrounded by 6 long papillae ..... 7. Bunodera
d_2 No such papillae.
e_1 Intestinal trunks reach to about the middle of the body.
f_1 Yolk glands branched and in middle area of body ..... 8. Renifer
f_2 Yolk glands compact and at end of body ..... 13. Microphallus
e_2 Intestinal trunks reach the rear end of body.
f_1 Genital pore near front end of body.
g_1 Genital pore near pharynx; in lungs of frogs and toads. 9. Pneumonœces
g_2 Genital pore in front of oral sucker ..... 10. Cephalogonimus
f_2 Genital pore near acetabulum; yolk glands compact and lobate.
g_1 Testes 2 in number ..... 11. Gorgoderina
g_2 Testes 9 in number ..... 12. Gorgodera
b_2 Ovary behind testes.
c_1 Hinder end of body not telescopic ..... 14. Halipegus
c_2 Hinder end telescopic ..... 15. Hemiurus
b_3 Ovary between the testes ..... 16. Clinostomum
a_2 Unisexual distomes ..... 17. Schistosoma

1. Fasciola L. Body broad and leaf-like, covered with minute spines and with a short conical anterior end at the base of which is the acetabulum; intestine, excretory vesicles, and genital glands richly branched; genital pore in front of acetabulum: in liver of herbivores; about 4 species.

F. hepatica L. Liverfluke. Length 18 to 50 mm.; width 4 to 13 mm.; conical anterior end distinctly set off; body thin and flat: in the gall passages of cattle, sheep, man, and other animals, causing liver rot, which is often very fatal to herds; intermediate host a snail of the genus Lymnæa; cosmopolitan, but rare in America, except in southern Texas, in Florida, and a few other places.

F. magna* (Bassi) (Fig. 299). Length 20 to 100 mm.; width 11 to 26 mm.; body flesh-colored and thick, with anterior end not distinctly

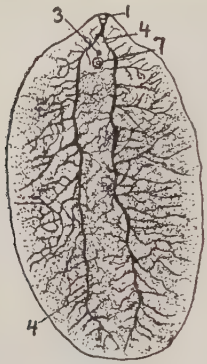

Fig. 299

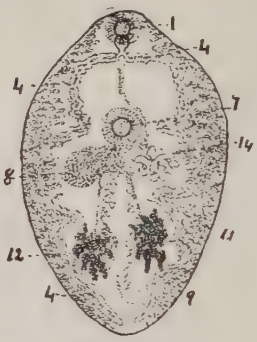

Fig. 300

Fig. 299—*Fasciola magna* (from Ward). References as in Fig. 293. Fig. 300—*Paragonimus westermani* (from Ward). References as in Fig. 293.

set off: in the gall passages of cattle; common in the southwestern states; life history unknown.

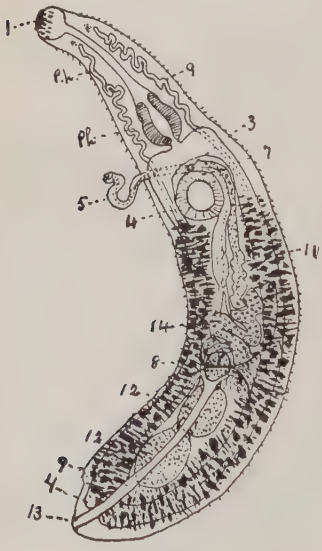

Fig. 301

Stephanochasmus casus, with extended cirrus (Pratt). P.p., prepharynx; Ph., pharynx. Other references as in Fig. 293.

2. **Paragonimus** Braun. Genital pore just behind the acetabulum; body thick, ovoid; intestinal trunks long and unbranched; testes lobate; yolk glands very voluminous; uterus very short: encapsuled in the lungs of mammals; 1 species.

P. westermani (Kerbert) (Fig. 300). Body red in color, 8 to 20 mm. long; 4 to 8 mm. wide: in lungs of cats, dogs, and in eastern Asia, in man.

3. **Echinostoma** Rudolphi. Body elongate and spiny; acetabulum near front end; mouth surrounded by a reniform ridge in which is a row of spines, interrupted midventrally: many species.

E. echinatum (Zeder). Number of spines about 37; body 18 mm. long; 1.5 mm. wide: in intestine of ducks, chickens, geese, and swans.

4. **Stephanochasmus** Looss. Body elongate and spiny; acetabulum near forward end; mouth surrounded by 2 rows of spines: several species, in fishes.

* See "The Anatomy of the Large American Fluke," etc., by C. W. Stiles, Jour. Comp. Med., etc., March, 1894—May, 1895.

S. casus Linton (Fig. 301). Number of spines 36, 18 in each row; body 6 mm. long; 1 mm. wide: in rectum of the gray snapper.

5. **Amphimerus*** Barker. Body lanceolate; acetabulum in forward half with the genital pore in front of it; ovary near the center of the body; yolk glands divided into two regions; testes, which may be lobate, in a row behind it with the excretory vesicle winding between them: several species, in land vertebrates.

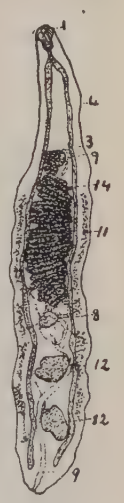

Fig. 302 *Amphimerus pseudofelineus* (Ward). References as in Fig. 293.

A. pseudofelineus (Ward) (Fig. 302). Body not spinose; length 10 to 21 mm.; width 1 to 2.5 mm.: in the liver of cats.

6. **Azygia** Looss. Body elongate; acetabulum near the middle, ovary far back of it, and between the two is the uterus; testes back of ovary: in fish.

A. loossi Marshall and Gilbert. Length 6 mm.; breadth .5 mm.; body not spinose; yolk glands back of acetabulum: in mouth and stomach of wide-mouthed black bass, pike, and dogfish.

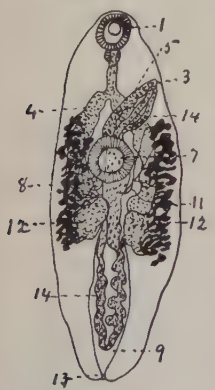

Fig. 303—*Renifer ellipticus* (Pratt). References as in Fig. 293.

7. **Bunodera** Raillet. Body ovate; mouth surrounded by 6 contractile projections; acetabulum near center of body, with genital pore in front of it; testes in hinder part of body; uterus sac-like: in fresh-water fish.

B. nodulosa (Zeder). Length 1 to 3 mm.: in the intestine of the perch and other fishes; intermediate host the crayfish, being found in cysts in various organs.

8. **Renifer**† Pratt. Body elongate and spinose; acetabulum near the middle of the body with the genital pore between it and the oral sucker; ovary just back of acetabulum; testes lobate and just back of ovary: in reptiles.

R. ellipticus Pratt (Fig. 303). Body elliptical; genital pore at left edge of body; 4 mm. long: in mouth of *Heterodon platyrhinus*, the blowing viper, and other snakes.

9. **Pneumonœces**‡ Looss. Body elongate; suckers small, acetabu-

* See "The Trematode Genus Opisthorchis," by F. D. Barker. Arch. d. Parasit., Vol. 14, p. 513, 1911.

† See "Descriptions of Four Distomes," by H. S. Pratt, Mark Ann. Vol., p. 25, 1903.

‡ See "On the American Representatives of Distomum variegatum," by J. Stafford, Zool. Jahrb. Abt. f. Sys., Bd. 16, p. 895, 1902.

lum often minute; ovary and testes back of acetabulum; large receptaculum seminis present; uterus usually in longitudinal folds: in lungs of amphibians; 8 species.

P. similiplexus (Stafford) (Fig. 304). Length 8 mm.; width 2 mm.; body spinose; testes small; uterus very voluminous and dark-colored: in the lungs of frogs and toads.

Fig. 304
Pneumonœces similiplexus (Stafford). References as in Fig. 293.

10. **Cephalogonimus** Poirier. Body broad, spinose; acetabulum near center of body; yolk glands; genital pore in front of oral sucker; excretory vesicle extensively branched; ovary just back of acetabulum and testes back of it: in turtles.

C. vesicaudus Nickerson. Body elliptical, 2 mm. long: in intestine of soft-shell turtles in Minnesota.

11. **Gorgoderina** Looss. Body elongate and without spines; acetabulum large and in forward half of body; back of it are the yolk glands, which are a pair of compact bodies; the ovary is back of these; testes 2 in number; uterus fills the hinder half of the body: 4 species, in urinary bladder of frogs and toads.

G. translucida (Stafford) (Fig. 305). Body widest in the middle and tapering to both ends; 9.5 mm. long and 1.2 mm. wide: in the toad and the spring frog.

Fig. 305
Gorgodorina translucida (Stafford). References as in Fig. 293.

12. **Gorgodera** Looss. Like *Gorgoderina,* but with 9 testes in 2 rows in the hinder half of the body: 2 species.

G. amplicava Looss. Body widest in middle; acetabulum very large; length 3.75 mm., and .75 mm. wide: in the urinary bladder of the bullfrog.

13. **Microphallus** Ward. Body broad with blunt ends; intestinal cœca very short and not reaching acetabulum; yolk glands lobate, in hinder part of body; genital pore at left of acetabulum: in fresh-water fish.

M. opacus (Ward) (Fig. 306). Length 1.7 mm.; width 1 mm.; œsophagus very long: in intestine of *Amia calva;* intermediate host *Cambarus propinquus.*

14. **Halipegus** Looss. Body elongate; acetabulum in middle of body; yolk glands 2 compact lobate bodies near hinder end; ovary in front of them and testes in front of ovary: in amphibians.

H. occidualis Stafford. Body 6 mm. long; 1.5 mm. wide; testes in oblique plane near acetabulum: in the mouth of frogs.

15. Hemiurus Rudolphi. Small, cylindrical worms, the hinder end of whose bodies forms an appendix which can be invaginated; cuticula transversely striped; yolk glands compact, behind ovary, which is just behind the testes: in fish.

H. appendiculatus (Rud.). Appendix from a third to twice the length of the body; acetabulum much larger than oral sucker; yolk glands spherical; 6 mm. long: in digestive tube of herring and other marine fish; intermediate host usually copepods.

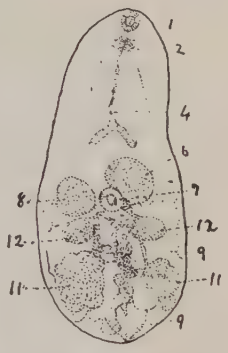

Fig. 306.—*Microphallus opacus* (Ward). References as in Fig. 293.

16. Clinostomum Leidy. Elongated worms with mouth surrounded by a circular ridge; ovary between the testes in middle of body; intestine without pharynx and with side projections: in mouth of birds; about 10 species.

C. marginatum (Rudolphi) (Fig. 307). Body 6 to 10 mm. long; 1 to 2 mm. wide; yolk glands voluminous: in *Ardea* and other birds; intermediate host, the sunfish and other fishes.

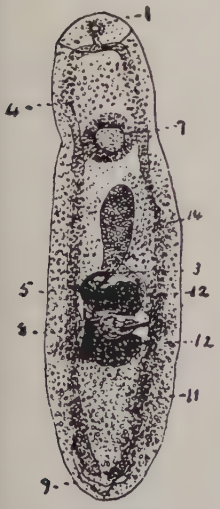

Fig. 307 *Clinostomum marginatum* (Osborn). References as in Fig. 293.

17. Schistosoma Weinland. Sexes separate; acetabulum near front end; male is larger than the female and has a deep groove in its ventral side in which the filiform female lies: several species, in blood of mammals in tropical countries.

S. hæmatobium (Bilharz) (Fig. 308). Body cylindrical; length of male 14 mm.; length of female 20 mm.: in the blood of man, chiefly in Africa, occasionally in this country.

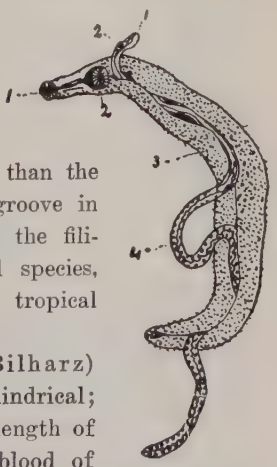

Fig. 308 *Schistosoma hæmatobium* (Looss). 1, oral sucker; 2, acetabulum; 3, male individual; 4, female individual.

Division 4. **HOLOSTOMATA.**

Digenetic trematodes with an oral sucker and an acetabulum, and in addition a large variously constructed adhesive ventral disc or pro-

jection situated just back of the acetabulum; body in most cases made up of 2 distinct regions, a wider anterior portion containing the 2 suckers and the disc, the lateral edges of which are often rolled in ventrally and medially, and a posterior portion containing the genital organs; the genital openings being at the hinder end in a deep depression called the bursa copulatrix; the arrangement of the internal organs is similar to that of the *Distomata:* in the intestine of vertebrates, principally mammals and birds; about 6 genera and 60 species.

Key to the genera of *Holostomata* here described:

a_1 Lateral edges of anterior portion not rolled in medially....1. DIPLOSTOMUM
a_2 Edges of anterior portion rolled in.
b_1 Anterior portion trough-shaped.....2. HEMISTOMUM
b_2 Edges of anterior portion fused midventrally.....3. STRIGEA

1. **DIPLOSTOMUM** Nordmann. Body composed of 2 distinct portions; a large sucking disc back of the acetabulum: in the intestine of the *Crocodilia* and of birds; intermediate hosts, fish; about 15 species.

D. grande Diesing. Oral sucker and acetabulum small; sucking disc at the bottom of a deep cavity, the opening of which is on a conical projection just back of the acetabulum; length 4 mm.: in the intestine of the snowy owl.

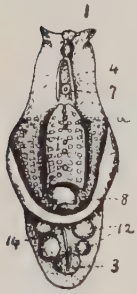

Fig. 309

Fig. 310

Fig. 309—*Hemistomum alatum* (Brandes). a, adhesion elevation. Other references as in Fig. 293. Fig. 310—*Strigea variegata* (Brandes). a, adhesion elevation; m, mouth; b, genital bursa; c, cup-shaped anterior end.

2. **HEMISTOMUM** Diesing. Anterior portion of body flattened, the lateral edges being prolonged medially, forming a trough; behind the acetabulum and sometimes projecting over it is an elongated adhesive elevation: in the liver of birds and mammals; about 15 species.

H. alatum (Goeze) (Fig. 309). Length 6 mm.; acetabulum smaller than the oral sucker, at each side of which is a crescent-shaped opening of glands: in the stomach and intestine of the fox and dog.

3. **STRIGEA** Abildgaard (*Holostomum* Rudolphi). Lateral edges of the forward portion of the body prolonged medially and joined midventrally, making this part of the body cup-shaped; behind the acetabulum is a conical adhesive elevation in a deep cavity: in the intestine of birds, rarely in fish and amphibians; about 30 species.

S. variegata (Dujardin) (Fig. 310). Conical elevation usually projecting from the cup; length 6 mm.; testes branched; genital bursa at hinder end: in gulls, grebes, and loons.

Class 3. **CESTODES.*** (Tapeworms.)

Soft, flat parasitic worms in which the body is made up of two distinct parts, a head or scolex and a strobila. The scolex contains either simple or complex suckers and often hooks, the organs of attachment: the strobila is composed of a series of similar segments or proglottids, each of which contains a complete set of male and female genital organs. In the simplest cestodes, however, no segmentation of the body occurs and but one set of genital organs is present (Fig. 312). The cestodes are digenetic entoparasites which, with a few exceptions, live in two different hosts; as adults they live in the intestine of a vertebrate as final host, and as larvae in the muscles or some other compact tissues of an intermediate host. The latter is some animal which is preyed upon or occasionally eaten by the final host.

The scolex is without a mouth or organs of special sense. The suckers are mostly 2 or 4 in number; their place is sometimes taken by variously formed sucker-like projections called bothria (Fig. 319). Accessory suckers (Fig. 318) are also sometimes present, and in a few forms the entire scolex is absent or rudimentary and the anterior proglottids are modified to form a so-called pseudoscolex, by means of which the animal attaches itself. Hooks are often present on the scolex to assist the parasite in maintaining its position. In the *Tæniidae* they are situated on a central elevation called the rostellum, and in the *Rhynchobothriidae* on four long retractile projections called proboscides.

Behind the scolex is usually a narrow unsegmented region called the neck, after which come the proglottids or segments, which are derived by a process of terminal budding from the scolex and may number from three to several thousand in number, in the different species. The segments nearest the scolex are the youngest and smallest, those at the opposite end of the strobila are the oldest and the largest. In *Crossobothrium,* however, and probably also in other cestodes, a different and much more complex method of growth has been observed,† new segments budding towards the scolex as well as away from it. The genital organs are usually

* See "Die Parasiten des Menschen," etc., by R. Leuckart, 1879. "Cestodes," by M. Braun, Bronn's Klassen, etc., Bd. 4, p. 927, 1894 to 1900. "Tapeworms of Poultry," C. W. Stiles, Bull. No. 12, Bureau An. Ind., 1896. "Parasites of Fishes of the Woods Hole Region," by E. Linton, Bull. U. S. Fish. Com., Vol. 19, p. 405, 1900. "Die thierischen Parasiten des Menschen," by M. Braun, 1903. "Parasites of Fishes of Beaufort," by E. Linton, Bull. of Bur. of Fish., Vol. 24, p. 321, 1905. "Illustrated Key to the Cestode Parasites of Man," by C. W. Stiles, Bull. 25, Hygienic Lab., Wash., 1906. "Tænoid Cestodes of North American Birds," by B. H. Ransom, Bull. U. S. Nat. Mus., 1909. "Die Süsswasserfauna Deutschl.," by M. Lühe, 1910. "Index Catalogue," etc. "Cestoda and Cestodaria," by C. W. Stiles and A. Hassall, Bull. 85, Hyg. Lab., Treas. Dep., 1912.

† See "The Formation of Proglottids in Crossobothrium laciniatum Linton," by W. C. Curtis, Biol. Bull., Vol. II, p. 202, 1906.

immature in the younger segments; those following contain the mature organs, and in the terminal segments these have in most species degenerated, except the uterus, which is swollen with eggs, each of which usually contains an embryo. In the typical human tapeworms these ripe segments are detached and pass out of the body of the host to the outside, where they break open and the young are scattered. In the *Bothriocephaloidea,* however, the eggs are laid in the intestine of the host and pass out with the feces, the terminal segments often containing no eggs. In some fish tapeworms the segments are detached before they are ripe and remain free in the intestine. The outer surface of the body is an unciliated cuticula, while the interior contains a vesicular parenchyma, in which muscle fibers as well as the other internal organs and usually also calcareous concretions lie. No digestive system is present, nutrition being carried on by absorption through the outer surface of the body. The excretory system consists typically of two pairs of longitudinal canals, one pair being near each lateral margin, which open to the outside in the terminal segment. The two canals on each side are not of the same size, the ventral being smaller than the dorsal and often disappearing altogether. The dorsal and the ventral pair are very often connected by a cross canal in each segment, and fine branches extend throughout the parenchyma containing flame cells. The nervous system consists of a number of longitudinal nerves extending the length of the body connected in each segment by a ring commissure; in the scolex is a pair of large ganglia forming the brain and usually other ganglia, joined with one another by a complex system of commissures.

Cestodes, with rare exceptions, are hermaphroditic animals, each segment containing both male and female organs; in some species each segment contains two sets of genital organs, one on each side (Fig. 322). The genital pores are situated either in the margin or in the ventral surface of the segment. In the lowest cestodes there are three such pores, through which the vas deferens, the vagina, and the uterus, respectively, open to the outside (Fig. 315, B). In most cestodes the vas deferens and vagina pass to a genital atrium which has a single external opening, and no special uterine pore is present (Fig. 327, B). The arrangement of the reproductive organs is complex and varies considerably in the different groups of cestodes.

Habits and Distribution.—The typical embryo of the tapeworm is a minute spherical animal called the onchosphere or six-hooked embryo (Fig. 311), which is provided with three pairs of locomotory hooks. Having been swallowed by its first or intermediate host, either in drinking water or on the food of the latter, it works its way by means of its hooks into the blood vessels and may be carried with the blood to various parts of

the body of the host. It imbeds itself in a muscle or other organs and develops into a characteristic larva called a bladder worm. This larva is in some cases exactly like the scolex of the adult worm and is then called a plerocercus. In other cases it contains besides the scolex some or all of the strobila, sometimes with the genital organs, and is called a plerocercoid. In still others it is an ovoid vesicle filled with a fluid and containing one or more scolices and no proglottids and is called a cysticercus, or a minute vesicle completely filled with an invaginated scolex and called a cysticercoid. This larva remains quiescent in the intermediate host, but if this animal be devoured by the final host the larva is transferred to the intestine of the latter and, at once attaching itself to the intestinal wall, begins to produce the strobila. In a few weeks or months the entire worm is usually formed.

Fig. 311—A, Egg of *Tænia saginata* containing a six-hooked embryo; B, same egg without the external membrane (Leuckart).

Cestodes are among the most pronounced animal parasites and are found in all countries and in all of the larger animals. Man and his domestic animals are especially liable to infection and may be the hosts of some very dangerous tapeworms.

History.—The common tapeworms of man, including both the adult and the larval worm, have been known to science from the time of the Greeks. The name *Tænia* for a tapeworm occurs in Pliny, and the name *Tænia solium* has been employed since the Middle Ages, when it was given to all the common tapeworms. The order *Cestodes* was established in 1808 by Rudolphi. It included however only the adult worms, the larval worms being placed by Rudolphi in the separate order *Cystici*. The relation of the adult to the larval worms was not then understood, notwithstanding the fact that Goeze and Pallas in the previous century had both clearly indicated it, Rudolphi and all the important helminthologists of his time believing that tapeworms may develop by spontaneous generation in the places where they are found. In fact it was not until 1851 that it was finally demonstrated by Küchenmeister that the bladder worm is the larval stage of the adult worm. This investigator showed that if *Cysticercus pisiformis* be fed to a dog *Tænia serrata* will very shortly appear in the dog's intestine. He and others afterwards repeated the experiment with the tapeworms of the cat and of man and of other animals. In the case of the human tapeworms the cysticerci were given to condemned criminals and the adult worms were invariably found in their intestines after death. Rudolf Leuckart has since been the most active in the study of the entire group.

The class contains not far from 1,000 species, which are distributed among 2 subclasses.

Key to the subclasses of *Cestodes:*

a_1 No scolex; no segmentation; embryo with 10 hooks.....1. CESTODARIA

a_2 Body usually segmented and with a scolex; embryo with 6 hooks.
2. CESTODES, *s. str.*

SUBCLASS 1. CESTODARIA.

Small, unsegmented worms which live in fishes as adults and in mollusks and annelids as larvae; no distinct scolex is present although the forward end has a contractile papilla or a sucker; but 1 set of genital organs present; uterus a winding tube with an external opening; embryo with 10 locomotory hooks and called a lycophora: 2 genera and about 4 species.

1. GYROCOTYLE* Diesing (Fig. 312). Body leaf-like and elliptical, with fluted margins; a small sucker at one end and a peculiar "rosette" organ at the other end with a retractile proboscis: 4 species.

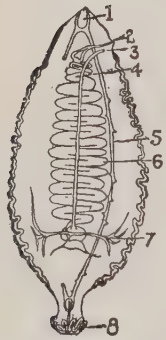

Fig. 312
Diagram of *Gyrocotyle* (Spencer from Watson).
1, sucker; 2, male genital pore; 3, vagina; 4, uterine pore; 5, nerve; 6, uterus; 7, yolk duct; 8, rosette.

G. fimbriata Watson. Length up to 55 mm.; width 10 mm.; in intestines of *Chimæra;* California.

2. AMPHILINA Wagener. Body flat and leaf-like: forward end with a small sucker, beside which is the uterine pore; at the opposite end are the openings of the cirrus and the vagina: 2 species.

A. foliacea (Rudolphi). Length 20 mm.: in the body cavity of sturgeons.

SUBCLASS 2. CESTODES—*Sensu stricto.*

Body, except in rare cases, segmented, with a scolex, which, however, may be rudimentary or replaced by a pseudoscolex; uterus with an external opening only in the *Bothriocephaloidea;* vas deferens and vagina open usually into a genital cloaca which opens to the outside by a single pore: 5 orders and about 90 genera.

Key to the orders of *Cestodes* here described:

a_1 Uterine pore present; genital organs do not degenerate in the ripe segments.....1. BOTHRIOCEPHALOIDEA

a_2 No uterine pore; ripe segments contain the gravid uterus and little else.

b_1 Proboscides not present in scolex.

c_1 Four bothria usually present; yolk glands paired; principally in fishes.
2. TETRAPHYLLIDEA

c_2 Four suckers present; yolk glands not paired; in land vertebrates.
3. CYCLOPHYLLIDEA

b_2 Four retractile proboscides present in scolex; in fishes.4. TRYPANORHYNCHA

* See "The Genus Gyrocotyle," etc., by E. E. Watson, Univ. of Cal. Pub., Vol. 6, p. 353, 1911.

Order 1. BOTHRIOCEPHALOIDEA.

Body often long, with or without distinct segmentation; scolex with 2 suckers, one in the dorsal and one in the ventral surface, which are usually weak and in certain forms are highly modified by the extension of their edges, and may be rudimentary or wanting, when their place may be taken by a single accessory sucker or a pseudoscolex; a uterine or birth pore present in the ventral surface; the other two genital pores also usually ventral but may be dorsal or marginal; testes numerous; ovary either distinctly or indistinctly paired and in the hinder part of the segment; yolk glands paired in the lateral areas of the segment; the genital organs do not degenerate: about 4 families; either adult or larval form usually in fishes.

Key to the families of *Bothriocephaloidea* here described:

a_1 Uterus an irregularly coiled tube.....1. Diphyllobothriidae
a_2 Uterus not a coiled tube, usually sac-like.....2. Ptychobothriidae

Family 1. DIPHYLLOBOTHRIIDAE.

Scolex usually without hooks, segmentation in most cases distinct, but sometimes wanting; cirrus (penis) without spines; uterus a long tube coiled back and forth across the segment: 4 subfamilies and about 15 genera.

Key to the subfamilies of *Diphyllobothriidae* here described:

a_1 Two suckers present.
b_1 Scolex very short; no neck present.....1. Ligulinae
b_2 Scolex elongate; neck usually present.....2. Diphyllobothriinae
a_2 But 1 sucker.....3. Cyathocephalinae

Subfamily 1. LIGULINAE.

Scolex short, triangular, with small suckers and without hooks; genital pores ventral: in the intestine of water birds as adults; larva a plerocercoid which may be as large as the adult and is found free in the body cavity of fishes: 2 genera.

1. Ligula Bloch. Suckers and external segmentation wanting in the larva, and only the forward portion externally segmented in the adult, these segments, however, not corresponding to the internal segmentation: 1 species.

Fig. 313 *Ligula intestinalis* (forward end) (from Braun).

L. intestinalis (L.) (Fig. 313). Length up to 40 cm. or more; width 10 mm.: in perch, pike, and other fresh-water fish as a larva, and in gulls and other water birds as adult.

2. Schistocephalus Creplin. Suckers and external segmentation present and distinct in the larva as well as the adult, and internal and external segmentation identical: 1 species.

S. gasterostei (Fabricius) (Fig. 314). Length up to 30 cm.: in *Gasterosteus* and other fish and also the frog as a larva, and in water birds as adult.

Fig. 314—*Schistocephalus gasterostei*. A, forward end (Linton); B, fish containing the larval worm (Cambridge Natural History).

SUBFAMILY 2. DIPHYLLOBOTHRIINAE.

Scolex without hooks and with either 2 small suckers or highly modified suckers; segmentation distinct; cirrus and vagina open into a genital cloaca, the pore of which is ventral and in front of the uterine pore: 6 genera; in higher vertebrates.

1. DIPHYLLOBOTHRIUM Cobbold (*Bothriocephalus* Rudolphi; *Dibothriocephalus* Lühe). Scolex flattened laterally with 2 deep slit-like suckers; strobila long; uterus a long tube coiled zigzag: over 50 species; in carnivorous mammals and water birds.

D. latum (L.) (Fig. 315). Length up to 9 m., with several thousand segments; onchosphere ciliated and free-swimming: larva a plerocercoid 30 mm. long found in the perch and many other fishes; adult worm in man, also in the cat and dog, and common in certain localities, especially where fish is much eaten; in this country rare.

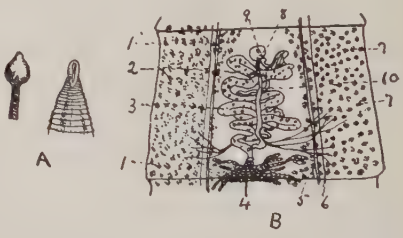

Fig. 315—*Diphyllobothrium latum* (Leuckart). A, anterior end, showing suckers; B, mature segment. 1, yolk gland; 2, birth pore; 3, uterus; 4, ovary; 5, excretory canal; 6, nerve; 7, testes; 8, vaginal pore; 9, male genital pore (cirrus); 10, uterine pore.

Fig. 316 *Cyathocephalus truncatus* (Zschokke).

SUBFAMILY 3. CYATHOCEPHALINAE.

Scolex usually with a single terminal sucker; outer segmentation indistinct or wanting; genital pores either ventral or dorsal or both: 1 genus.

CYATHOCEPHALUS Kessler. With the characters of the subfamily: 1 species.

C. truncatus (Pallas) (Fig. 316). Length up to 20 mm.; with about 6 segments: in the pyloric cœca of the whitefish.

FAMILY 2. PTYCHOBOTHRIIDAE.

Scolex without hooks, with 2 suckers more or less developed, each of which may be converted into a pocket by the partial fusion of its

walls, or may be subdivided into 2 portions, of which the hinder may have the appearance of a separate sucker; a pseudoscolex may also take the place of the scolex; uterus usually an extensive sac, which may occupy the greater part of the segment with a ventral opening; pore for cirrus and vagina either marginal or dorsal: 7 genera; in fishes.

1. Abothrium van Beneden. Suckers shallow; a cylindrical pseudoscolex may be present in place of the scolex, the hinder margin of which is prolonged backwards so as to project over the strobila; segmentation of hinder part indistinct; cirrus and vaginal pores marginal, that of uterus medium: 3 species.

A. rugosum (Batsch). Length 25 cm. or more; breadth 4.7 mm.: in the intestine of the cod; often common.

2. Bothriocephalus Rudolphi (*Dibothrium* Diesing). Scolex elongate with rather weak suckers; no accessory suckers; segmentation often indistinct; neck not present; uterine opening midventral; common genital pore for cirrus and vagina middorsal: about 4 species.

B. lacinatus (Linton). Body 15 cm. long, 4 mm. broad in the middle, tapering towards hinder end; segmentation distinct, the posterior margins of the proglottids projecting backwards, making the margin of the strobila serrate: in *Tarpon atlanticus*.

Order 2. TETRAPHYLLIDEA.

Scolex with 4 bothria, which vary much in form, being either stalked or not and with or without hooks and accessory suckers; a pseudoscolex may replace the scolex; segmentation distinct; cirrus and vagina open on the margin; no uterine pore; yolk glands paired: 4 families and about 30 genera; in selachians, and also in other fish, amphibians, and reptiles.

Key to the families of *Tetraphyllidea* here described:

a_1 Hooks present at the forward end of each bothrium....1. Onchobothriidae
a_2 No such hooks.....2. Phyllobothriidae

Family 1. ONCHOBOTHRIIDAE.

Hooks of various shape present in the anterior rim of the bothria; bothria either sessile or with short stalks; accessory suckers usually present; the segments usually detach themselves before sexual maturity: in spiral valve of selachians; 9 genera.

1. Calliobothrium van Beneden. Bothria elongate, each being divided by 2 transverse septa into 3 divisions of unequal size and with either 1 or 3 small accessory suckers and 2 or 4 simple hooks: several species.

C. verticillatum (Rudolphi). Length up to 15 cm.; length of terminal segment about 3.5 mm., width 1.7 mm.; a 3-lobed accessory sucker and 4 hooks in front of each bothrium; body very slender, resembling

a white hair; scolex the size of a small pinhead: often common in spiral valve of the smooth dogfish.

2. **Phoreiobothrium** Linton. Bothria rectangular and elongate, without subdivisions; an accessory sucker and 2 three-pronged hooks at the forward end of each bothrium; neck long, with minute spines: 1 species.

Fig. 317
Scolex of *Phoreiobothrium lasium* (Linton).

P. lasium Linton (Fig. 317). Length 4 cm.; terminal segment about 2.2 mm. long and .84 mm. wide: in spiral valve of the dusky shark.

Family 2. PHYLLOBOTHRIIDAE.

Scolex without hooks; bothria usually stalked and with or without septa subdividing them, and with or without a myzorhynchus, which is a central, stalked sucker rising from midst of the bothria, and other accessory suckers: about 12 genera.

Key to the genera of *Phyllobothriidae* here described:

a_1 Bothria without transverse septa and myzorhynchus.
  b_1 Bothria without accessory suckers.....1. Anthobothrium
  b_2 Bothria with accessory suckers.
    c_1 Each bothrium with 2 suckers.....2. Orygmatobothrium
    c_2 Each bothrium with 1 sucker.
      d_1 Edges of bothria not or but little convoluted.....3. Crossobothrium
      d_2 Edges of bothria very much convoluted.....4. Phyllobothrium
a_2 Bothria with 2 septa and with a myzorhynchus.....5. Echeneibothrium

1. **Anthobothrium** van Beneden. Bothria very contractile, oval in shape, stalked, their edges not or but little folded; without accessory suckers; body elongate: several species.

A. laciniatum Linton. Length up to 21 mm.; length of terminal segment about 1.8 mm., width 1 mm.: in spiral valve of sand shark and other sharks; often numerous.

Fig. 318
Crossobothrium laciniatum (Curtis).

2. **Orygmatobothrium** Diesing. Bothria stalked, with a larger accessory sucker in the middle and a smaller one at the forward end of each, which may be confluent; neck long: several species.

O. paulum Linton. Length 9 mm.; breadth of terminal segment about .28 mm., length 1.03 mm.: in spiral valve of the tiger shark; often very numerous.

3. **Crossobothrium** Linton. Bothria stalked, each with an accessory sucker at the forward end, and with its rim more or less convoluted; body elongate: 1 species.

C. laciniatum Linton (Fig. 318). Length up to 25 cm.; segmentation occurs at certain times in both directions, making the middle segments the youngest: in the spiral valve of the sand shark; common.

4. Phyllobothrium van Beneden. Bothria sessile or nearly so, with very convoluted edges and with an anterior accessory sucker; neck very long: several species.

P. foliatum Linton. Length up to 18 cm.; length of terminal segment about 1.4 mm., width .9 mm.: often numerous in spiral valve of the sting ray.

Fig. 319
Scolex of Echeneibothrium variabile (Braun).

5. Echeneibothrium van Beneden. Bothria stalked, elongate or oval, and very contractile, the face of each being subdivided by 1 or 2 longitudinal and several transverse septa; myzorhynchus present but may be wanting in old worms: several species.

E. variabile v. Ben. (Fig. 319). Length about 10 cm.; neck long: in the spiral valve of the common skate; often common.

Order 3. CYCLOPHYLLIDEA.

Body usually elongate; scolex with 4 simple cup-shaped suckers, between which a protrusile rostellum with hooks is usually present; segmentation distinct; no uterine pore; common genital pore usually marginal; yolk gland unpaired and usually behind the paired ovary: 10 families and about 50 genera which live principally in the higher vertebrates; larva a cysticercus or cysticercoid, so far as known.

Key to the families of *Cyclophyllidea* here described:

a_1 Uterus transverse in position and either tubular, sac-like, or reticulate.
  b_1 Scolex without hooks.....1. Anoplocephalidae
  b_2 Scolex with hooks.
    c_1 No hooks in the suckers.....2. Dipylidiidae
    c_2 Suckers armed with hooks.....3. Davaineidae
a_2 Uterus consists of a median stem and side branches.....4. Tæniidae

Family 1. ANOPLOCEPHALIDAE.*

Scolex more or less spherical, without hooks but with large suckers; segments short and wide; uterus transverse in position and tubular, sac-like, or reticular: in mammals; 8 genera.

Key to the genera of *Anoplocephalidae* here described:

a_1 Genital pore on but one side of the segment.
  b_1 Genital pores on the same side of all the segments.....1. Anoplocephala
  b_2 Genital pores regularly or irregularly alternate.....2. Bertia
a_2 Genital pores on both sides of the segment.
  b_1 Uterus reticulate and double.....4. Moniezia
  b_2 Uterus tubular.
    c_1 Uterus a thick tube, single or double: in rodents.....3. Cittotænia
    c_2 Uterus undulate: in sheep.....5. Thysanosoma

* See "A Revision of the Adult Tapeworms of Hares and Rabbits," by C. W. Stiles, Proc. U. S. Nat. Mus., Vol. 19, p. 145, 1896.

1. **Anoplocephala** Blanchard. Segments much broader than long; genital pores all on the same side of the segments and never on both sides: about 16 species; in horses and rodents.

Fig. 320—Anterior end of *Anoplocephala perfoliata* (Ward).

A. perfoliata (Goeze) (Fig. 320). Length up to 8 cm.; scolex large, square, with 4 projections extending backwards, 2 being dorsal and 2 ventral: in the ileum, cæcum, and colon of the horse, often in large numbers.

2. **Bertia** Blanchard. Segments broader than long; genital pores regularly or irregularly alternate, but never on both sides of a segment: in apes, monkeys, and rodents; about 6 species.

B. americana (Stiles). Length 33 mm.; width 6 mm.; with about 90 segments; no calcareous concretions: in porcupines; often common.

3. **Cittotænia*** Riehm. Segments broader than long with genital pores on both sides; 2 sets of genital organs and 1 or in some cases 2 simple, transverse, tubular uteri in each segment; vagina always ventral to the cirrus: in rodents; 7 species.

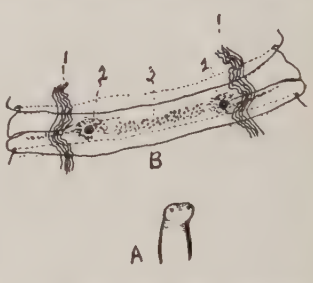

Fig. 321—*Cittotænia variabilis* (Stiles). A, head; B, a segment. 1, excretory canals; 2, ovary; 3, testes.

C. variabilis (Stiles) (Fig. 321). Length up to 18 cm.; breadth 10 mm.; cirrus pouch tubular, of equal diameter throughout; testes form a band in the median area between the ovaries: in the cotton-tail rabbit and the marsh hare.

4. **Moniezia**† Blanchard. Segments broader than long with genital pores on both sides; 2 sets of genital organs and 2 complex reticulate uteri in each segment; vagina ventral on right side and dorsal on left side to cirrus; interproglottidal glands along hinder margin of the segment: 6 species; in ruminants.

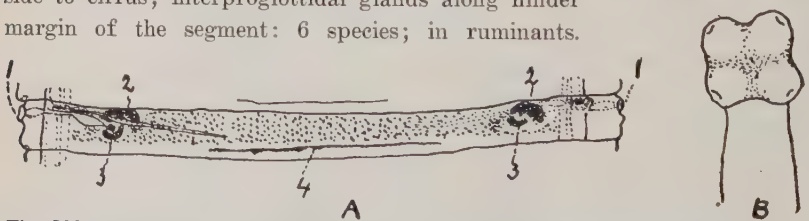

Fig. 322—*Moniezia planissima* (Stiles). A, a segment; B, head. 1, genital pore; 2, ovary; 3, yolk gland; 4, interproglottidal gland.

M. planissima Stiles and Hassall (Fig. 322). Body very broad and flat and up to 2 m. long, and 26 mm. broad; interproglottidal glands

* See "Studies on the Genus Cittotænia," by R. A. Lyman, Stud. from Zool. Lab., Univ. of Neb., No. 48, 1902.

† See "A Revision of the Adult Cestodes of Cattle, Sheep," etc., by C. W. Stiles and A. Hassall, Bull. No. 4, Bur. Animal Ind., 1893.

elongate and not in groups: in small intestine of sheep and cattle; often common.

M. expansa (Rudolphi) (Fig. 323). Body up to 4 m. long and 26 mm. wide, and often quite thick; interproglottidal glands a straight row of round sacs: in sheep, cattle, deer, and goats; common.

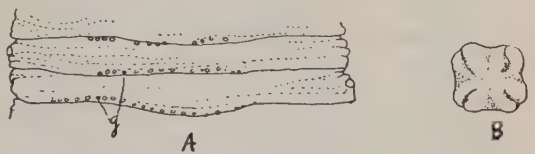

Fig. 323—*Moniezia expansa* (Stiles). A, two segments; B, end view of head; g., interproglottidal glands.

5. **Thysanosoma**

Diesing. Segments broader than long with genital pores on both sides or only on one side, and either 2 or 1 set of genital organs; a single uterus in each segment consisting of an undulating, transverse tube with side pockets: 2 species, in sheep.

Fig. 324—*Thysanosoma actinoides* (Stiles). A, head, side view and ventral view; B, segments.

T. actinoides Dies. The fringed tapeworm (Fig. 324). Length up to 30 cm.; width 8 mm.; head prominent; neck very flat and broad; hinder margin of each segment fringed: common in the west.

Family 2. DIPYLIDIIDAE.

Scolex usually with hooks on a rostellum; uterus made up of a large number of egg sacs, or it may be absent, in which case the eggs are distributed throughout the parenchyma; larva a cysticercoid: in birds, mammals, and reptiles; 10 genera.

Fig. 325 *Dipylidium caninum* (from Ward).

1. **Dipylidium** Leuckart. Rostellum retractile and with hooks; genital pores and organs double in each segment; uterus reticular: 1 species.

D. caninum (L.) (*D. cucumerinum* Rudolphi) (Fig. 325). Length up to 25 cm.; breadth 3 mm.; ripe segments about 7 mm. long and 3 mm. wide and often reddish in color: in cats and dogs, and occasionally in young children; cysticercoid in the dog's flea; common.

2. **Hymenolepis*** Weinland. Small filiform worms with broad segments with the genital pores all on the left and never on both sides;

* See "An Account of the Tapeworms of the Genus Hymenolepis Parasitic in Man," by B. H. Ransom, Bull. No. 18, Hyg. Lab., 1904.

rostellum retractile and with or without hooks; 3 testes in each segment; with a sac-like uterus filling the ripe segment: about 30 species; in mammals and birds.

H. nana (von Siebold). The dwarf tapeworm (Fig. 326). Length 15 mm. or more; breadth .7 mm.; scolex with a single row of about 28 hooks: in the small intestine of man and the rat and mouse; the cysticercoid lives in the intestinal villi of the same host; the parasite often causes diarrhea and nervous attacks.

Fig. 326 *Hymenolepis nana* (Leuckart).

H. carioca (Magalhæs). Length up to 8 cm.; width .7 mm.; rostellum without hooks; edge of strobila serrate: in chickens; common.

H. dimnuta (Rudolphi). Length up to 6 cm.; width 4 mm.; rostellum rudimentary, without hooks: in cats and mice.

Family 3. DAVAINEIDAE.

Scolex with hooks on a retractile rostellum and numerous small hooks in the suckers; genital pore usually on only one side of a segment: 3 genera; in mammals and birds.

Davainea Blanchard and Railliet. Small worms; eggs in capsules in the middle area of the ripe segment: about 15 species.

D. salmoni Stiles. Length 88 mm.; breadth 3 mm.; number of segments about 450; genital pores generally alternate: in *Lepus sylvaticus* and *L. melanotis*.

Family 4. TÆNIIDAE.

Scolex usually with a rostellum with hooks; uterus, in the ripe segment, composed of a median tube and lateral branches; usually long worms with segments longer than wide; genital pores alternating irregularly and never on both sides of a segment: several genera.

1. Tænia L. With the characters of the family: numerous species, which are usually found in predacious mammals and man, the cysticercus being found in ruminants and other plant feeders.

T. saginata Goeze. The beef tapeworm (Fig. 327). Length 10 m. or more, with over a thousand segments, usual length 4 to 8 m.; terminal segments about 20 mm. long and 7 mm. broad, containing a uterus which has from 20 to 30 branches on each side; scolex 2 mm. thick, without rostellum or hooks: in the human intestine; the cysticercus (*C. bovis*) is about 9 mm. long and 5 mm. thick and lives in the muscles of cattle, and a person may infect himself with the worm by eating rare beef; the commonest human tapeworm in this country.

T. solium L. The pork tapeworm (Fig. 328). Length about 3 m., with about 900 segments; terminal segment about 12 mm. long and

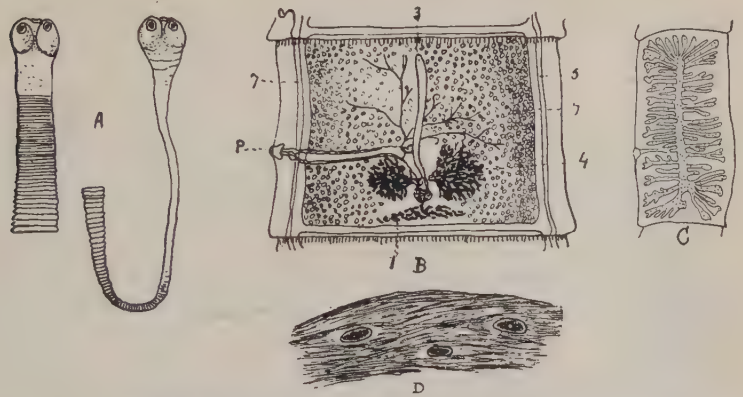

Fig. 327—*Tænia saginata* (Leuckart). A, head with the anterior segments; B, a segment about a third of the distance back from the head; C, terminal segment; D, a piece of beef containing three cysticerci; P, common genital pore. Other references as in Fig. 315.

6 mm. wide, containing a uterus which has from 7 to 10 branches on each side; scolex about 1 mm. thick with a rostellum bearing a double row of about 28 hooks: in the human intestine; the cysticercus (*C. cellulosae*) is from 6 to 20 mm. long and about half as wide and thick and lives normally in the muscles of the pig, but also lives readily in man, being found in the eye, brain, heart, and other organs and causing often insanity or death; rare in this country.

T. marginata Batsch. The large dog tapeworm. Length up to 3 m.; terminal segments 10 mm. long and 5 mm. wide, containing a uterus with from 4 to 8 branches on each side; rostellum with 2 rows of about 38 hooks: in the dog; cysticercus (*C. tenuicollis*) in the viscera of pigs and ruminants; not common in this country.

T. serrata Goeze. The serrate dog tapeworm. Length up to 1 m.; terminal segments 10 mm. long and 5 mm. wide, containing a uterus with 8 to 12 branches on each side; edge of strobila serrated; rostellum with 2 rows of about 40 hooks: in the dog; cysticercus (*C. pisiformis*) about the size of a small pea, in the peritoneum of rabbits and hares; common.

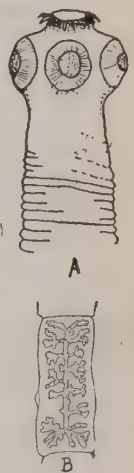

Fig. 328 *Tænia solium* (Leuckart). A, head B. terminal segment.

T. crassicollis Rudolphi. The cat tapeworm. Length up to 60 cm.; terminal segments 10 mm. long and 6 mm. wide, containing a uterus with about 10 branches on each side; rostellum with 2 rows of

about 50 hooks: in the cat; cysticercus (*C. fasciolaris*) in the liver of the mouse and rat, where it forms a conspicuous tumor, and is peculiar in that it consists of a scolex and a number of segments, the latter, however, degenerating on arriving in the cat's intestine and the scolex developing a new strobila; very common.

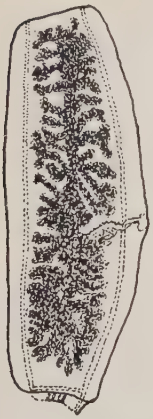

Fig. 329—*Multiceps multiceps* (Ransom), ripe segment.

2. **Multiceps** Goeze. Like *Tænia* but with a large cysticercus from the inner wall of which many scolices project into the interior: about 6 species.

M. multiceps (Leske) (*Tænia cœnurus* von Siebold). The gid tapeworm* (Fig. 329). Length up to 60 cm.; terminal segments 5 mm. long and 2 mm. broad, containing a uterus with about 22 branches on each side; rostellum with 2 rows of about 30 hooks: in the dog; cysticercus (*Cœnurus cerebralis*), which is 25 mm. in diameter or larger and spherical and contains hundreds of scolices, lives in the brain or spinal cord of sheep and occasionally cattle, causing gid or staggers; northwestern states; Europe; often killing great number of sheep.

3. **Echinococcus** Rudolphi. Like *Tænia,* but with a large cysticercus from the inner wall of which capsules of scolices project into the interior: several species.

E. granulosus (Batsch) (*Tænia echinococcus* von Siebold). The echinococcus tapeworm (Fig. 330). Length up to 5 mm., with but 3 or 4 segments; rostellum prominent, with 2 rows of about 40 hooks: in the dog; cysticercus (*Echinococcus polymorphus*) lives in the liver or other organs of sheep, pigs, cattle, or other animals, and also in man, when it is called a hydatid cyst, and as it may grow to be half a foot in diameter and to weigh several pounds and contains thousands of scolices, it may cause death; often common in Europe but apparently rare in this country; infection obtained directly from the hair or tongue of dogs.

Fig. 330 *Echinococcus granulosus* (Braun).

Order 4. TRYPANORHYNCHA.

Scolex very long, composed of 2 portions, a head which has 2 or 4 bothria and 4 retractile and spinose proboscides, and a long head stalk;

* See "The Gid Parasite," etc., by B. H. Ransom, Bull. 66, Bur. An. Ind., U. S. Dept. Ag., 1905. "The Gid Parasite," etc., by M. C. Hall, Bull. 125, ditto, 1910.

segmentation distinct; genital pores marginal; genital organs with the same arrangement as in the *Tetraphyllidea:* in the intestine of selachians; larvae encysted in teleosts; 2 families.

FAMILY RHYNCHOBOTHRIIDAE.

With the characters of the orders: numerous genera, concerning the value and position of many of which much uncertainty prevails.

1. **RHYNCHOBOTHRIUS** Rudolphi. Two bothria, one dorsal and one ventral, which tend to converge at their forward ends: many species.

R. bulbifer Linton (Fig. 331). Bothria oval; neck long and slender; length of body up to 40 mm., with 12 or less segments: in spiral valve of *Mustelus canis;* cysts in mackerel, bluefish, and other teleosts; common.

2. **TETRARHYNCHOBOTHRIUM** Diesing. Four bothria present; head stalk cylindrical; many species.

T. robustum (Linton). Bothria elongate; length of body 24 mm.; segments usually broader than long: in stomach and intestine of skate; common.

Fig. 331
Rhynchobothrius bulbifer (Linton).

CLASS 4. NEMERTEA.*

Nemerteans. Soft, very contractile, and often brightly colored flatworms, most of which are non-parasitic and live in the sea. The body is usually elongate and more or less tape-like or filiform, varying in length from 5 mm. to 30 m. in the different species; it is unsegmented, but often has an annulated appearance due to the regularly repeated subdivisions of certain of the internal organs. The mouth is in the ventral surface near the front end and the anus is at the hinder end of the body. Dorsal to the mouth (Fig. 332) is an opening into a very deep tubular pocket, extending far back into the body, a portion

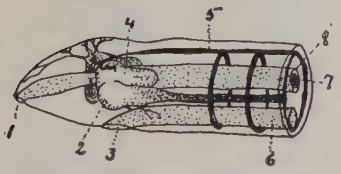

Fig. 332—Diagram of nemertean worm — lateral aspect (Bürger). 1, proboscis pore; 2, ventral ganglion; 3, mouth; 4, dorsal ganglion; 5, dorsal nerve; 6, intestine; 7, proboscis; 8, proboscis sheath.

* See "Marine Nemerteans of New England and Adjacent Waters," by A. E. Verrill, Trans. Conn. Acad., Vol. 8, p. 382, 1892. "Die Nemertinen," Fauna u. Flora d. Golfes v. Neapel, by O. Bürger, 1895. "Nemertini," Kl. u. Ordn., Vol. 4, Supp., 1897. "On the Connective Tissues and Body Cavities of the Nemerteans, with Notes on Classification," by T. H. Montgomery, Jr., Zool. Jahrb. Anat., Vol. 10, p. 1. "Notes of the Times of Breeding of Some Common New England Nemerteans," by W. R. Coe, Science N. S., Vol. 9, p. 167, 1899. "Nemertini," by O. Bürger, Das Tierreich, 1904. "Synopsis of the Nemerteans, Part I," by W. R. Coe, Am. Nat., Vol. 39, p. 425. "Nemerteans of the West and Northwest Coast of North America," by W. R. Coe, Bull. Mus. Comp. Zool., Vol. 47, 1905.

of which can be everted and thrust forward in the form of a proboscis (Fig. 333): in most hoplonemerteans this opening coincides with the mouth. The proboscis is often nearly as long as the body itself and can be thrust out far in advance. It is primarily a tactile organ and in the hoplonemerteans is armed with calcareous stylets of characteristic form, indicating that it has also an offensive function. Dorsal to the proboscis in most species are the openings of the so-called cephalic glands. In *Malacobdella* a large sucker is present at the hinder end, and *Nectonemertes* possesses a pair of lateral swimming organs. Many heteronemerteans have a caudal cirrus at the posterior end. The outer surface of the body is a glandular, ciliated epithelium and is often brightly colored.

No body cavity is present, the spaces between the organs being filled with a gelatinous parenchyma. The proboscis, however, is surrounded by a muscular sheath containing a corpusculated fluid (Fig. 333, 4). The digestive canal extends the whole length of the body, and is usually differentiated into œsophagus, stomach, intestine, and rectum. The intestine is often provided with regularly recurring paired diverticula and in the hoplonemerteans has a long intestinal cæcum, extending forward to near the front end of the body. Two or three longitudinal blood vessels with connecting branches and containing a corpusculated fluid differing somewhat from that in the proboscis sheath extend the length of the body and are connected with large blood spaces. A pair of profusely branched longitudinal excretory canals lie alongside the lateral blood vessels in the anterior portion of the animal, which usually open to the outside through one or more pores on each side of the body. Minute branches of these canals extend into the parenchyma and end in flame cells. The central nervous system consists of a four-lobed brain and a pair of large lateral nerves (Fig. 332) extending to the hinder end of the body, where they join; a dorsal median nerve is also usually present and in some species a ventral median one as well. A pair of lateral ciliated canals called the cerebral organs because they

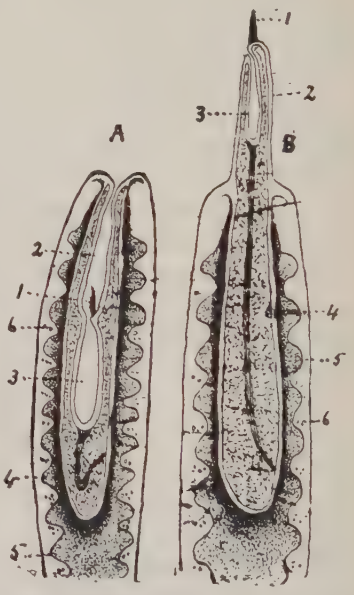

Fig. 333—Diagram of nemertean worm—dorsal aspect. A, with proboscis retracted; B, with proboscis extended (altered from Boas). 1, stylet; 2, proboscis; 3, poison gland; 4, proboscis sheath; 5, intestine; 6, gonads.

lie in close relation to the dorsal cerebral lobes occur in most nemerteans: these are represented by a pair of lateral sensory grooves in many paleonemerteans. In the hoplonemerteans and some heteronemerteans also occur one to three supraoral or frontal organs, which are sensitive protuberances capable of being retracted so as to form a pit. Simple ocelli, each with lens and nerve, occur in most nemerteans. The number of such ocelli, which in a few forms are scattered along the sides of the body, may exceed 200. A few species have auditory sacs. The muscular system is well developed, consisting of two or three layers of circular and longitudinal muscles which bear an intimate relation to the main nerves.

Most nemerteans are unisexual, but a few are hermaphroditic. The gonads are paired, spherical organs, which usually lie between the intestinal diverticula (Fig. 333) and discharge their products directly through the body wall to the outside, no permanent genital ducts being present. A few are viviparous. Development is direct in many forms, while in others the young animal leaves the egg as a free-swimming larva (pilidium or Desor's larva) and passes through a complicated metamorphosis before acquiring the form of the parent.

History.—The *Nemertea* have only quite recently been given an independent systematic position, having been formally grouped with the *Turbellaria*. The name originated with Cuvier, who in 1815 gave the generic name *Nemertes* to *Lineus longissimus*. Johnston (1846) first employed the name for the entire group. At the present time it is a matter of dispute whether the *Nemertea* should be grouped with the *Plathelminthes* or be given an independent position. The modern classification is due principally to Hubrecht and Bürger. The class contains over 400 species grouped in 4 orders, 87 species having been found on our Pacific and 62 species on our Atlantic coast.

Key to the orders of *Nemertea:*

a_1 No sucking disc present; intestine not convoluted.
  b_1 Proboscis without stylets; mouth behind brain; intestinal cæcum absent.
    c_1 Muscular walls of body usually in 2 layers; eyes usually absent. 1. PALEONEMERTEA
    c_2 Muscular walls of body in 3 main layers; eyes usually present. 2. HETERONEMERTEA
  b_2 Stylets usually present; mouth in front of brain; intestinal cæcum usually present. 3. HOPLONEMERTEA
a_2 Sucking disc present; intestine convoluted. 4. BDELLONEMERTEA

ORDER 1. PALEONEMERTEA. (PROTONEMERTINI; MESONEMERTINI.)

Body long and slender, often filiform; mouth usually far back, being always behind the brain; proboscis without stylets; cerebral organ and eyes usually absent; body wall contains two muscle layers, an outer

circular, an inner longitudinal, to which a third, an inner circular, is sometimes added; lateral nerves either external to the muscles or imbedded in the longitudinal layer; cutis absent: 4 families, all marine.

Key to the families of *Paleonemertea* here described:

a_1 Paired intestinal diverticula absent.....1. CARINELLIDAE
a_2 Paired intestinal diverticula present.....2. CEPHALOTRICHIDAE

FAMILY 1. CARINELLIDAE.

Cerebral organs represented by a pair of lateral epithelial depressions; brain and lateral nerves lie in the outer epithelium or just beneath it; mid-dorsal blood vessel usually absent; inner circular muscles encircling the proboscis sheath and intestine very thick: 5 genera and about 27 species.

CARINELLA Johnston. Body cylindrical and filiform, with the head end large and distinctly set off; intestinal diverticula absent; lateral sense organs usually present near the paired excretory pores, consisting each of a round ciliated depression: 16 species, principally on the Pacific coast.

C. pellucida* Coe. Body very small, whitish in color, up to 25 mm. long and .5 mm. thick: not uncommon among annelid tubes at low water and below in Long Island and Vineyard Sounds; California.

FAMILY 2. CEPHALOTRICHIDAE.

Body long and very slender, usually filiform; cerebral organ and eyes usually absent; mouth behind the brain; body wall contains two muscle layers, an outer circular and an inner longitudinal, with the brain and longitudinal nerves lying in the latter layer: 2 genera and about 12 species.

Fig. 334
Cephalothrix linearis (Verrill). m, mouth.

1. **CEPHALOTHRIX** Oersted. Body filiform, tapering at the forward end, which is pointed; no excretory canals; inner circular muscles absent; the worm coils the body in a spiral: about 7 species.

C. linearis (Rathke) (Fig. 334). Body whitish, yellowish, or flesh color, up to 15 cm. long and 1 mm. thick; mouth very far back; proboscis very long and slender: Long Island Sound to Nova Scotia; Pacific coast; Europe; often common between tide lines, under stones and in the sand; breeds in August at Woods Hole.

2. **CARINOMA** Oudemans. Body rather thick, cylindrical in front, flattened behind: 4 species.

* See "Descriptions of Three New Species of New England Paleonemerteans," by W. R. Coe, Trans. Conn. Acad., Vol. 9, p. 515, 1895.

C. tremaphoros C. B. Thompson. Body 12 cm. long, 3 mm. thick, buff in color; head white, flattened, rounded in front: Woods Hole.

Order 2. HETERONEMERTEA. (Schizonemertea.)

Body often very long; mouth behind brain; proboscis without stylets; cerebral organ present; a caudal cirrus sometimes present; body wall contains three muscle layers of which the outer is longitudinal and between which and the circular muscles are the lateral nerves; cutis well developed: 2 families and over 170 species.

Family LINEIDAE.

Body usually very long, but in some species relatively short and thick; a pair of conspicuous lateral sensory grooves usually on the head; 3 muscle layers in proboscis; the outer one being longitudinal; cephalic gland small and slender: 10 genera and about 150 species.

Key to the genera of *Lineidae* here described:

a_1 Caudal cirrus not present.
  b_1 Lateral sensory grooves wanting.....1. Parapolia
  b_2 Lateral sensory grooves present.....2. Lineus
a_2 Caudal cirrus present.
  b_1 Lateral sensory grooves wanting.....3. Zygeupolia
  b_2 Lateral sensory grooves present.
    c_1 Lateral body edges not thin; animals cannot swim.....4. Micrura
    c_2 Lateral body edges very thin; animals swim.....5. Cerebratulus

1. Parapolia Coe. Body cylindrical anteriorly, flattened posteriorly; head not set off from body; without sensory grooves on the head; eyes not present; cerebral organs a pair of flat elevations: 1 species.

P. aurantiaca Coe. Color orange; length 25 cm.; width 10 mm.; thickness 4 mm.: Vineyard Sound, at low-water mark.

2. Lineus Sowerby. Body extremely long and filiform or tape-like and very contractile; head somewhat wider and tapering to a point; usually with eyes: about 50 species; cosmopolitan; animals cannot swim, and usually twist themselves into an irregular mass.

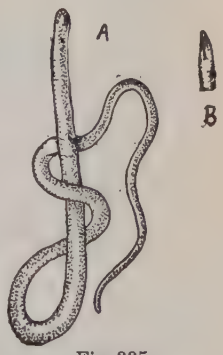

Fig. 335
Lineus ruber (Verrill). A, whole worm; B, head, showing lateral groove.

L. ruber (O. F. Müller) (*L. gesserensis* O. F. Mül.; *L. viridis* Johnston) (Fig. 335). Body cylindrical; color very variable, being green, brown, or reddish; a single row of 4 to 8 eyes on each side of head; 20 cm. or more; width 6 mm.: common under stones in shallow water from Long Island to Greenland; Alaska; Europe; breeds in June at Woods Hole.

L. socialis (Leidy). Body very slender and flattened, 25 cm. long and 5 mm. wide, green or brown in color; ventral side lighter than dorsal; a single row of 4 to 6 very small eyes on each side of the head and a single pair of larger eyes some distance in front of the others: common from New Jersey to Bay of Fundy, living gregariously under stones, between tide lines; breeds in mid-winter in Long Island Sound.

L. bicolor Verrill. Body small, 45 mm. long, 1.5 mm. wide, cylindrical but somewhat flattened, dark green with a mid-dorsal yellowish stripe; with a single row of 8 to 14 eyes on each side: among algae and hydroids in shallow water in Vineyard and Long Island Sounds; very common in certain localities.

3. **Zygeupolia** C. B. Thompson. Body cylindrical anteriorly and flattened posteriorly; head very long and pointed and without lateral sensory grooves; caudal cirrus present: 1 species.

Fig. 336 Fig. 337

Fig. 336—*Micrura leidyi* (Verrill).
Fig. 337—*Cerebratulus lacteus* (Verrill).

Z. rubens (Coe) (*Z. litoralis* C. B. Thom.*). Body slender and 8 cm. long; head pure white; body whitish: coast of New England; southern California; on sand flats between tide lines.

4. **Micrura** Ehrenberg. Small, flat, and soft nemerteans with a caudal cirrus, which cannot swim; with 3 frontal organs; often with many eyes: about 17 species.

M. cæca Verrill. Body dark brown or yellow; 10 cm. long and 2 mm. wide; no eyes: Long Island and Vineyard Sounds, at low-water mark; sexually mature in July and August at Woods Hole.

M. leidyi (Verr.) (Fig. 336). Body thick anteriorly; flattened posteriorly; 15 cm. long and 4.5 mm. wide; red or purple dorsally, usually with a lighter median line and lighter ventrally; proboscis flesh color: common from New Jersey to Cape Ann in the sand near low-water mark; breeds in mid-summer.

5. **Cerebratulus** Renier. Body long, flat, and broad, with a small pointed head and thin edges well adapted for swimming; eyes usually absent; mouth a long slit; with 3 frontal organs; proboscis very long; a caudal cirrus at hinder end: over 60 species; in all seas.

* See "Zygeupolia litoralis," etc., by C. B. Thompson, Proc. Acad. Nat. Sci., Phila., Vol. 53, p. 657, 1901.

C. lacteus* (Leidy) (Fig. 337). Body 2 m. or less long and 25 mm. wide; extreme length up to 6.5 m.; flesh color; proboscis white: very common in the sand near low-water mark from Florida to Maine; breeds from March to May in Long Island Sound and in July in Casco Bay.

Order 3. HOPLONEMERTEA. (Metanemertini.)

Body often very long and slender, but in many forms short and thick; mouth in front of the brain, usually coinciding with the opening of the proboscis; intestinal cæcum present; proboscis provided with stylets (Fig. 333); lateral nerve cords internal to the muscle layers of the body wall; frontal sense organ present: 9 families and more than 200 species, which live in the sea, in fresh water, and on land; a few species parasitic; development usually direct.

Key to the families of *Hoplonemertea* here described:

a_1 Proboscis does not reach the hinder third of the body. 1. Emplectonematidae
a_2 Proboscis reaches almost to the hinder end of body.
  b_1 Four eyes usually present, forming a quadrangle.
    c_1 Mostly hermaphroditic; long, thin worms, some terrestrial. 2. Prosorhochmidae
    c_2 Unisexual worms, short and thick ..... 4. Prostomatidae
  b_2 Eyes numerous ..... 3. Amphiporidae

Family 1. EMPLECTONEMATIDAE.

Body very long and thin; proboscis short and thick and with a single main stylet of variable form; usually with very small eyes: 5 genera and about 25 species.

Fig. 338—*Emplectonema gracile* (Coe).

1. Emplectonema Stimpson. Mouth and proboscis openings coincide; usually with many eyes, never only four; accessory stylets present: 16 species.

E. gracile (Johnston) (Fig. 338). Head end wider than body and with 20 to 30 eyes on each side; length about 20 cm.; breadth 1.5 mm.; color green; stylets slender and curved at the end: very common on Pacific coast north of San Francisco, in shallow water; Europe.

2. Carcinonemertes† Coe. Body long and slender, cylindrical, usually not coiled; mouth and proboscis coincide, the latter being

* See "On the Anatomy of a Species of Nemertean (Cerebratulus lacteus Verrill)," by W. R. Coe, Trans. Conn. Acad., Vol. 9, p. 479, 1895. "The Habits and Early Development of Cerebratulus lacteus," by C. B. Wilson, Quart. Jour. Micros. Sci., Vol. 43, 1900.

† See "Nemertean Parasites of Crabs," by W. R. Coe, Am. Nat., Vol. 36, p. 431, 1902.

rudimentary and without accessory stylets; 2 minute eyes: 2 species; parasitic on crabs.

C. carcinophila (Kölliker). Body 15 mm. long when immature, and 40 mm. long when mature; color red: on *Portumanus (Platyonichus) ocellatus* of the New England coast and on *Carcinus mœnas* and other crabs of the European coast, being on the gills when immature and on the eggs when mature.

Family 2. PROSORHOCHMIDAE.

Body long and thin, but rather broad; 4 eyes usually present, forming a transverse quadrangle: 3 genera and 15 species; marine or terrestrial.

Geonemertes Semper. Body slender and long, but of small size; proboscis as long as the body with a central and 2 or 4 accessory stylets; hermaphroditic or unisexual, viviparous or oviparous: terrestrial, occurring in subtropical islands, or imported into greenhouses; usually under stones or in rotting wood; about 8 species.

G. agricola (Willemœs-Suhm). Body 35 mm. long and 2 mm. wide, very variable in color, usually milk white, brownish, or greenish; hermaphroditic and viviparous: common near and in mangrove swamps in Bermuda.

Family 3. AMPHIPORIDAE.

Body usually relatively short and thick; intestinal diverticula branched and usually not alternating regularly with the gonads; proboscis with a single central stylet with a conical base and several accessory stylets; cerebral organs large; usually numerous eyes: 3 genera and over 70 species; in all seas.

Key to the genera of *Amphiporidae:*

a_1 Proboscis sheath without diverticula.
  b_1 Eyes extending posteriorly only to brain region.....1. Amphiporus
  b_2 Eyes extending posteriorly behind brain region.....2. Zygonemertes
a_2 Proboscis sheath with a small number of ventral diverticula..3. Proneurotes

1. **Amphiporus** Ehrenberg. Usually short and thick and very contractile worms which cannot swim or roll up spirally; with numerous eyes: over 70 species, including almost a third of all American nemerteans.

Key to the species of *Amphiporidae* here described:

a_1 Body yellow.....A. ochraceus
a_2 Body white.....A. imparispinosus
a_3 Body red.....A. angulatus

A. ochraceus Verrill (Fig. 339). Body somewhat flattened, with a somewhat broader head; yellowish in color; 7 cm. long and 3 mm. wide; eyes converging backwards: common between tide lines and beyond, under stones, etc., in Long Island and Vineyard Sounds; breeds in May and June.

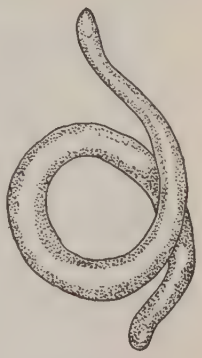

Fig. 339—*Amphiporus ochraceus* (Verrill).

A. imparispinosus Griffin. Body small, 25 to 50 mm. long; slender, slightly flattened posteriorly; white in color, sometimes with a reddish or yellowish tinge; ocelli in two groups on each side, converging anteriorly, less than forty in number: very common between tide lines, among algae, etc., on entire Pacific coast.

A. angulatus (O. F. Müller). Body stout with convex back; reddish or brownish in color; 15 cm. long and 8 mm. wide; head wider and set off from body, white in front with white spot on each side and an H-shaped figure in the middle; eyes numerous: common under stones between tide lines and beyond, from Cape Cod to Greenland; Puget Sound and northwards.

2. **Zygonemertes** Montgomery. Body long and slender; head broader than neck, with two pairs of lateral oblique furrows; ocelli very numerous, extending back along the sides of the body: 3 species.

Fig. 340
Zygonemertes virescens (Verrill).
A, whole worm; B, forward end.

Z. virescens (Verrill) (Fig. 340). Body slender and rather flat, usually light green in color, up to 4 cm. long and 1.5 mm. wide; eyes numerous, in two or three parallel lateral rows along the side of the body: common between tide lines and beyond in Long Island and Vineyard Sounds; California.

3. **Proneurotes** Montgomery. Like *Amphiporus*, but with 5 midventral diverticula in the proboscis sheath: 1 species.

P. multioculatus Mont. Body yellowish-brown in color with numerous eyes in two groups; 20 mm. long and 3 mm. wide: New Jersey coast; between tide lines.

Family 4. TETRASTEMMIDAE.

Body flat and slender or short and stout; 4 eyes usually present; intestinal diverticula and gonads alternate regularly; cerebral organs in front of the brain: 3 genera and about 75 species; in all seas, also in fresh water.

Key to the genera of *Tetrastemmidae:*

a_1 Marine animals.
  b_1 Body rather flat, soft in appearance.....1. TETRASTEMMA
  b_2 Body cylindrical, rigid in appearance.....3. OERSTEDIA
a_2 Fresh-water animals.....2. STICHOSTEMMA

1. TETRASTEMMA Ehrenberg. Body small, with the 4 eyes forming a rectangle; occasionally each eye is double or represented by a group; cephalic gland large; mostly unisexual, occasionally hermaphroditic: over 60 species.

Key to the species of *Tetrastemmidae* here described:

a_1 Body slender.
  b_1 Body widest at forward end, tapering to hinder end.
    c_1 Body whitish.....T. CANDIDUM
    c_2 Body more or less spotted.....T. VERMICULUM
  b_2 Body widest in the middle and tapering both ways.....T. ELEGANS
a_2 Body rather stout with dorsal stripes.....T. VITTATUM

T. candidum (O. F. Müller) (Fig. 341). Body very contractile and slender, white, light green, or yellowish in color, 2 cm. long and .5 mm. wide; head wide; hinder end tapering: common between tide lines and beyond, among algae, from Long Island Sound to Bay of Fundy; Europe.

Fig. 341 *Tetrastemma candidum* (Verrill).

T. elegans (Girard). Body slender, tapering from the middle both ways; back with a median yellow and 2 lateral brown stripes, 2 cm. long, 1 mm. wide: among eel grass and on stones in Long Island and Vineyard Sounds.

T. vermiculum (Quatrefages). Body slender, pale yellow or reddish in color and more or less spotted; forward end broader than the hinder, 2 cm. long, 1 mm. wide: common on muddy bottoms between tide lines in Long Island and Vineyard Sounds; Europe.

T. vittatum (Verrill). Body rather stout, green or yellowish in color, sometimes with 1 or 2 dorsal stripes, 5 cm. long, 4 mm. wide: common on muddy bottoms at low-water mark and beyond in Long Island and Vineyard Sounds.

2. STICHOSTEMMA* Montgomery. Similar to *Tetrastemma* but with 3 pairs of eyes; excretory organs extending the length of the body: 7 species, in fresh water.

S. rubrum (Leidy) (*S. asensoriatum* Mont.). Body slender, 18 mm. long, yellow or reddish in color and very transparent, with 6, rarely 4 or 8, eyes; preoral sense pit wanting; cephalic gland weak; hemaphroditic: Pennsylvania and Connecticut; eastern United States.

* "The Habits and Natural History of Stichostemma," by C. M. Child, Am. Nat., Vol. 35, 1901.

3. Oerstedia Quatrefages. Body cylindrical, of similar form at both ends, and rigid; 4 eyes forming a quadrangle; not over 15 mm. long: 4 species; marine.

O. dorsalis (Abildgaard) (Fig. 342). Body 10 mm. long and very slender; color variable, mottled with green, red, or brown: in shallow water on both the east and west coast of North America and in Europe, very common on piles and stones.

Fig. 342 *Oerstedia dorsalis*, showing the front end of the body with the protruded proboscis (Verrill).

Order 4. BDELLONEMERTEA.

Body short, flat, thick, and broad, with a large sucker at the hinder end; intestine without diverticula and convoluted; proboscis without stylets, its opening coinciding with the mouth and almost as long as the body; no eyes or cerebral organ: 1 genus and 3 species, living commensally in the branchial chamber of marine and fresh-water mollusks; cosmopolitan.

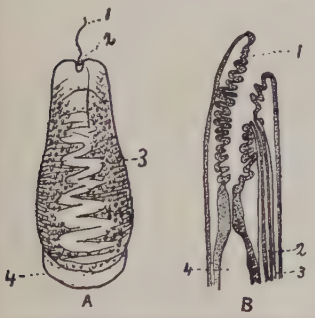

Fig. 343—*Malacobdella grossa*. A, entire worm (Verrill). 1, proboscis; 2, mouth; 3, intestine; 4, sucker. B, section through the forward end (Bürger). 1, mouth; 2, proboscis; 3, proboscis sheath.

Malacobdella Blainville. With the characters of the family: 3 species.

M. grossa (O. F. Müller) (Fig. 343). Hinder end of body broader than forward end; male 3 cm. long and 8 mm. broad, gray in color; female 26 mm. long and 13 mm. broad, yellowish or brownish in color: in *Mya arenaria, Venus,* and other pelecypods, on both sides of the north Atlantic.

Subphylum 2. NEMATHELMINTHES.*

Roundworms. Unsegmented, round worms, usually so elongated and slender that they are called thread or hair worms, which are entoparasites in animals or plants or lead a free life in the water or in moist earth. The body is not ciliated and is without paired appendages and usually without external bristles, hairs, or suckers. With a very few exceptions all are unisexual.

The subphylum contains 3 classes.

* See "The Determination of Generic Types and a List of Round Worms Genera and Their Original and Type Species," by C. W. Stiles and A. Hassall, Bull. 79, Bur. of An. Ind., Dept. of Ag., 1905.

Key to the classes of *Nemathelminthes:*

a_1 No spiny proboscis at forward end; intestine present.
b_1 Mouth and intestine not degenerate in adult; lateral lines present. 1. NEMATODA
b_2 Mouth and intestine degenerate; lateral lines absent.....2. GORDIACEA
a_2 Spiny proboscis present; no intestine.....3. ACANTHOCEPHALA

CLASS 1. NEMATODA.*

Threadworms (Fig. 344). Round, slender worms, usually white or flesh color in appearance, which vary from microscopic size to a meter in length. The integument consists of a cuticula which is usually smooth on the outer surface and a soft subcuticula; no hypodermis is present, but the subcuticula is supposed to represent it. There is a voluminous body cavity into which the subcuticula projects along the median dorsal and ventral and the two lateral lines, forming thus 4 prominent longitudinal ridges. In the lateral ridges run the paired excretory canals, which open to the outside by a pore just behind the mouth, and the lateral nerve cords; and in the dorsal and ventral ridges are also nerve cords. Lying next the subcuticula is a single layer of characteristic, longitudinal muscle fibers, no circular fibers being present. The nervous system consists of a nerve ring containing ganglion cells which surrounds the œsophagus and a number of longitudinal nerves extending both forwards and backwards, those going backwards being joined by transverse commissures. The only special sense organs are simple eyes, which some nematodes possess, and also sensory papillae.

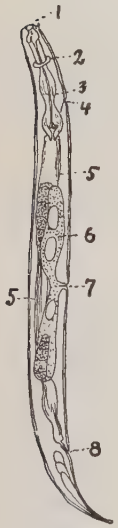

Fig. 344 Diagram of female nematode (Süssw. F. Deut.). 1, mouth 2, nerve ring 3, œsophagus 4, excretory pore 5, intestine 6, ovary 7, genital pore 8, anus.

The body cavity is without mesenteries, transverse septa, or peritoneal lining and contains blood. Lying in it are the alimentary canal and the reproductive organs. The mouth is at the forward end of the body and may be surrounded by sensory lips or papillae, and armed with chitinous teeth. The œsophagus is a muscular sucking-organ into which a pair of long glands may open; its hinder end may be constricted, causing the formation of one or two swollen divisions, called œsophageal bulbs. The intestine is a straight tube which passes to the anus near the hinder end of the body. The

* See "Monographie der Nematoden," by A. Schneider, 1866. "Die Süsswasserfauna Deutschlands," by L. A. Jägerskiöld and O. von Linstow, Heft 15, 1909. "The Nematodes Parasitic in the Alimentary Tract of Cattle, Sheep," etc., by B. H. Ransom, Bull. 127, Bur. An. Ind., 1911.

animals are, with a few exceptions, unisexual, the females being larger than the males, with a genital pore near the middle or towards the forward end of the body. The genital organs are simply formed tubular structures. In the male the testis is usually a single tube which communicates with the rectum. Anal papillae are often present; long spicules also usually project from the anus of the male by means of which it attaches itself to the female; in the *Strongillidae* and other families an expansion of the hinder end called the bursa also serves the same purpose. The spermatozoa are short and tailless. In the female two genital tubes are present which meet near the external opening. The distal ends of these are ovaries and produce the eggs while the proximal ends act as uteri. The eggs of the various species have a characteristic appearance by means of which the animals may be identified (Fig. 345). Many nematodes are viviparous, the young animals developing in the uterus.

Fig. 345—Eggs of various nematodes (from Ward). A, Ancylostoma duodenale; B, Necator americanus; C, Ascaris lumbricoides; D, Ascaris canis; E, Trichuris trichiura; F, Oxyuris vermicularis.

Habits and Distribution.—Nematodes are mostly active animals which move by a peculiar whipping motion of the body. With the exception of certain minute forms which lead a free life in fresh and salt water and in decaying organic matter, they are internal parasites of animals and plants, being among the commonest parasites of man and the domestic animals. Like most parasites, many pass through a metamorphosis in their youth and may live in two different hosts.

History.—Some of the commonest nematodes which are the cause of disease in man and his domestic animals have been known for a very long time and were much studied by the early zoologists. In 1808 Rudolphi created the orders *Nematoda* and *Acanthocephala,* and in 1851 Vogt formed a class of these two orders and the *Gordiacea,* which he called the *Nematelmia.* The most active investigators of nematodes at the present time in this country are the United States Department of Agriculture and the Marine Hospital Service.

The class contains about 15 families and several thousand species.

Key to the families of *Nematoda* here described:

a_1 Mostly non-parasitic nematodes.
b_1 Marine and free-swimming nematodes.....1. ENOPLIDAE
b_2 In fresh water or in the ground; a few parasitic in animals and plants.
2. ANGUILLULIDAE

a_2 Parasitic nematodes.
b_1 Parasitic in invertebrates; mouth with 6 papillae.....3. MERMITIDAE
b_2 Parasitic in vertebrates.

c_1 Mouth not surrounded by 3 prominent lips.
d_1 Body very long and filiform; 4 pairs of papillae around the anus of male.....4. FILARIIDAE
d_2 Anterior part of body with a very long and characteristic row of cells. 5. TRICHINELLIDAE
d_3 Male with a large bell-shaped bursa.....6. STRONGILIDAE
c_2 Mouth surrounded by 3 prominent lips.....7. ASCARIDAE

FAMILY 1. ENOPLIDAE.

Minute, free-living worms, found principally in the sea, but also in fresh water or in the earth; mouth often surrounded by hairs and bristles; œsophagus without bulb; eyes often present; male with spicules: numerous species.

1. **ENOPLUS** Dujardin. Body elongate, tapering behind; cuticula smooth; mouth with 6 papillae, behind which is a circlet of 10 to 12 bristles: numerous species in both salt and fresh water.

E. brevis Bastian. Lives among algae and hydroids in shallow water; often greenish in color; length 5 mm.

2. **DORYLAIMUS** Dujardin. Large worms; cuticula smooth, not ringed; extreme front end set off by a constriction; mouth with papillae and a large bristle: numerous species, which live at the roots of plants in moist earth and water.

D. maximus Bütschli. Length 7 mm.: in garden earth.

FAMILY 2. ANGUILLULIDAE.*

Minute worms which lead a free life in water or earth or decaying substances, or are parasitic in plants or (rarely) in animals; mouth without papillae; œsophagus with 2 bulbs; male with 2 spicules and sometimes with a bursa: numerous genera and species.

Key to the genera of *Anguillulidae* here described:

a_1 Free-living worms, in soil or decaying substances.
b_1 Mouth with 2 or 3 teeth.....2. DIPLOGASTER
b_2 Mouth without teeth.
c_1 In vinegar or paste.....1. ANGUILLULA
c_2 In the earth or decaying substances.....3. RHABDITIS
a_2 Parasitic worms.
b_1 Parasitic in plants; a spine in the mouth.
c_1 In the roots of vegetables.....4. HETERODERA
c_2 In wheat.....6. TYLENCHUS
b_2 Parasitic in animals.
c_1 In the bumble bee.....5. SPHÆRULARIA
c_2 In man.....7. STRONGYLOIDES

* See "Helminthological Contributions," No. 2, by J. Leidy, Proc. Acad. Nat. Sci., Phila., Vol. 5, p. 224. "Monograph of the Anguillulidae," by H. C. Bastian, Transact. Linn. Soc., London, Vol. 25, 1866. "On the Family Anguillulidae," etc., by J. Leidy, Proc. A. N. S., Phila., Vol. 22, p. 68, 1870.

1. Anguillula Ehrenberg. Cuticula smooth and ringed; body elongate, tapering behind; vulva behind the middle; spicules long; no bursa: several species.

A. aceti (O. F. Müller). Vinegar eel. Length 2 mm.: in vinegar, living on the fungus forming the "mother," also in stale paste; has also been found in the human bladder.

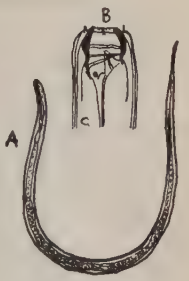

Fig. 346
Diplogaster rivalis (Süssw. F. Deut.). A, whole worm B, head.

2. Diplogaster M. Schultze. Body elongate; cuticula ringed and often ridged; body tapering behind; mouth with 2 or 3 teeth and often with papillae around it; male with or without bursa: numerous species; in fresh water, earth, and decaying substances.

D. rivalis Leydig (Fig. 346). Length 2 mm.; hind end tapering to a long, fine point; mouth surrounded by a membrane around which are 6 short bristles: viviparous; common in ponds and streams.

3. Rhabditis Dujardin. Minute worms living in decaying substances or the ground; head end often constricted: mouth triangular, usually with 3 to 6 lips; body slender, ending with a point; male with 2 short spicules: many species.

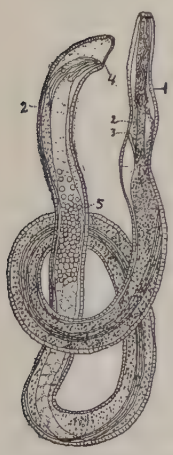

Fig. 347
Heterodera schachti (Stone and Smith).
1, pharynx; 2, intestine; 3, excretory pore; 4, genital pore and anus; 5, testes.

R. terricola Duj. Body without distinct rings, 1.4 mm. long; mouth cavity long, with 2 ring-shaped thickenings at its base: common.

4. Heterodera Schmidt. Minute worms infecting the roots of various plants, with a spine in the mouth for piercing plant tissues: 1 species.

H. schachti* Schmidt (*H. radicola* O. F. Müller) (Fig. 347). Male 1.5 mm. long, .045 mm. thick; female 1 mm. long and viviparous, being .5 mm. thick when full of young: in the roots of various vegetables and other cultivated plants, causing swellings.

5. Sphærularia Dufour. Minute worms, free-living and parasitic; male with a bursa; mouth with a tooth: 1 species.

S. bombi Duf. The young animals, about 1 mm. long, live in the earth; after pairing, the fertilized females migrate into the body of a hibernating queen bumblebee; here the uterus, filled with growing larvae, evaginates out of the vulva and

* See "Nematode Worms in the Greenhouse," by G. E. Stone and R. E. Smith, Bull. No. 55, Hatch Exp. Sta. of Mass., Ag. Col., 1898.

grows until it is many times the size of the rest of the worm, reaching a length of 15 mm.; the young larvae are born in the bee.

6. Tylenchus Bastian. Cuticula ringed; body tapering to a point behind; mouth with a spine for piercing plant tissues; vulva much back of the middle: numerous species, which are parasitic in plants.

T. tritici Bast. Male 2 mm., female 4.5 mm. long and spirally rolled together; color yellowish: in wheat, in a grain of which several larvae may live; when the wheat is sown the larvae migrate into the young plants and finally become mature in the buds; the eggs are laid here and the young larvae migrate into the ripening grain and remain there; they can lie in dried wheat for years without dying.

Fig. 348 *Strongyloides stercoralis* (Braun). A, hermaphroditic form B, larva.

7. Strongyloides Grassi. Minute worms with heterogony, a non-parasitic, unisexual generation alternating with an hermaphroditic parasitic generation, the former having a very long cylindrical œsophagus, the latter with a short œsophagus with a bulb; no teeth and 2 spicules present: 1 species.

S. stercoralis* (Bavay) (Fig. 348). Hermaphroditic form (*S. intestinalis* Bavay) 2.2 mm. long and .034 mm. wide, with an œsophagus a quarter as long as the body; vulva in the hinder part of the body: it lives in the human intestine and causes Cochin China diarrhœa, having been first observed in that country; a few large eggs are produced, from which hatch rhabditiform larvae, which are about .3 mm. long; they pass out with the feces and develop into the unisexual form, of which the male is .7 mm. and the female is about 1 mm. long, and which lead a free life; from their eggs the parasitic generation develops; in this country and Europe only the parasitic generation is known.

Family 3. MERMITIDAE.

Hairworms. Body long and filiform; mouth with 6 papillae; adults without anus; hinder part of the intestine solid; male with 2 spicules and 3 rows of papillae: the young animals live in the body cavity of insects, especially caterpillars, grasshoppers, and beetles, and occasionally spiders and snails or crayfish, from which they migrate into the ground or the water; here they become mature and lay their eggs; 1 genus.

Mermis† Dujardin. With the characters of the family: several species.

* See "Occurrence of Strongyloides intestinalis in the United States," by M. L. Price, The Jour. of the Am. Med. Asso., Vol. 41, 1903.

† See "Observations," etc., by J. Leidy, Proc. A. N. S., Phila., Vol. 5, p. 262. "A Synopsis of Entozoa," etc., by same. Ibid., Vol. 8, 1856, p. 42.

M. nigrescens Duj. (Fig. 349). Body 12 cm. long, .5 mm. thick, attenuated anteriorly and blunt behind; color white, with the black ovary showing through; the young worms migrate on warm summer days from the body of their hosts, often in large numbers, into the moist earth, causing a belief that they have rained down.

Fig. 349 *Mermis nigrescens* (Süssw. F. Deut.).

FAMILY 4. FILARIIDAE.*

Body very long and filiform; mouth often surrounded by papillae or by 2 lips; no œsophageal bulb; male with 1 spicule or with 2 of unequal size and with a spiral twist of the hinder end; usually viviparous: several genera.

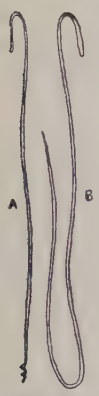

Fig. 350 *Filaria immitis* (from Braun). A, male B, female.

FILARIA O. F. Müller. Vulva towards the forward end; male with 2 spicules, and much smaller than the female: numerous species, which live in man and other vertebrates as final hosts, and probably in insects or crustaceans as intermediate hosts; Leidy mentions over 30 species in this country.

F. immitis† Leidy (Fig. 350). Length of male 18 cm.; thickness .9 mm., with a corkscrew hinder end; length of female 30 cm.; thickness 1.3 mm.: in the heart and veins of the dog, the .28 mm. long larvae appearing in the blood, especially in the night time; the larvae are transferred from one dog to another by mosquitoes; very common in China and Japan, and occurring in America and Europe; it sometimes infects man.

F. bancrofti Cobbold (Fig. 351). Male 4 cm. long, .1 mm. thick and colorless; female 8 cm. long, .28 mm. thick and brownish in color: in the heart and lymph vessels of man in the tropics, also in the southern United States, the .3 mm. long larvae appearing in the blood, but in the surface circulation only at night; the larvae are transferred from one person to another by mosquitoes; one of the causes of elephantiasis.

Fig. 351—*Filaria bancrofti* (from Braun), showing several worms among blood corpuscles.

F. loa (Cob.). Male 30 mm. long, .4 mm. thick, with 8 large circumanal papillae; female 41 mm. long and .5 mm. thick; body with

* See "The Zoological Characters of the Roundworm Genus Filaria," etc., by C. W. Stiles, Bull. 34, Hygienic Lab., etc., 1907.

† See "Notices of Nematoid Worms," by J. Leidy, Proc. A. N. S., Phila., 1886, p. 308.

numerous small protuberances, irregularly distributed: beneath the conjunctiva of the eye, in the eyelid, or in the subcutaneous tissue of other parts of the body in man; on the west coast of Africa and occasionally in America and Europe.

F. medinensis (L.). Medina or Guinea worm. Length of female 2 m. or less; thickness 1.7 mm.; color white or yellowish; intestine atrophied; male not known: in the subcutaneous tissue of man, especially in the legs, also in domestic animals, producing a sore which breaks to the outside, freeing the embryos; the young are found in *Cyclops* and are probably conveyed with drinking water into the human body; in Africa and other tropical countries, and supposed to be the "burning fiery serpents" which troubled the children of Israel in the desert.

Family 5. TRICHINELLIDAE.

Elongated worms with the forward portion attenuated, often extremely so; mouth without papillae or teeth; œsophagus slender, without bulb, and very long, in some cases being half as long as the body, and situated beneath a very characteristic row of conspicuously large cells; male with 1 spicule or none; female with but 1 ovary: 3 genera and numerous species, all internal parasites.

Key to the genera of *Trichinellidae:*

a_1 Forward portion very slender; whip worms.....1. Trichuris
a_2 Forward portion not whip-like.
b_1 Male without spicule.....2. Trichinella
b_2 Male with spicule.....3. Trichosoma

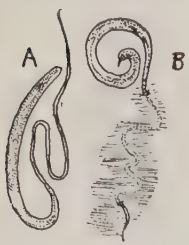

Fig. 352
Trichuris trichiura (from Braun). A, female; B, male, with the forward end imbedded in the intestinal mucous membrane.

1. **Trichuris** Roederer (*Trichocephalus* Goeze). Body made up of 2 portions, a very slender forward portion, containing the œsophagus, and a thick hinder portion, containing the reproductive organs; hinder end of male rolled up and with spicule; vulva at the forward end of the thick portion: in the large intestine, especially the cæcum, of mammals; development direct, infection resulting from swallowing the eggs; 1 species.

T. trichiura* (L.) (*Trichocephalus dispar* Rudolphi) (Fig. 352). Whip worm. Male 45 mm. long; female 50 mm. long; eggs (Fig. 345, E) ellipsoid, .05 mm. long and .023 mm. thick: in man, cosmopolitan; perhaps the commonest intestinal parasite in man and often the indirect cause of appendicitis and typhoid fever.

* See "A Statistical Study of the Prevalence of Intestinal Worms in Man." by C. W. Stiles and P. E. Garrison, Bull. No. 28 of Hygienic Lab., 1906.

2. **Trichinella** Railliet (*Trichina* Owen). Minute worms, with the forward portion not much slenderer than the hinder; male without spicule but with 2 conical projections at hinder end; viviparous; anus terminal: 1 species.

T. spiralis* (Owen) (Fig. 353). Male 1.5 mm. long; female 3.5 mm. long; young born alive: in the small intestine of man, the pig, rat, and other animals. The young worms, which are about .1 mm. long, are the cause of trichinosis. They bore their way through the intestinal wall of the host and migrate in the blood and lymph to the muscles, where they encyst themselves and frequently so lame the muscles of the jaws, neck, and thorax that their functioning is interfered with and death may ensue. If meat containing the cysts be eaten by another animal or a person the worm is released and passing into the intestine quickly becomes mature. Man gets the infection by eating insufficiently cooked pork containing the cysts; the pig gets it by eating offal or rats. The rat is supposed to be the original host of the worm.

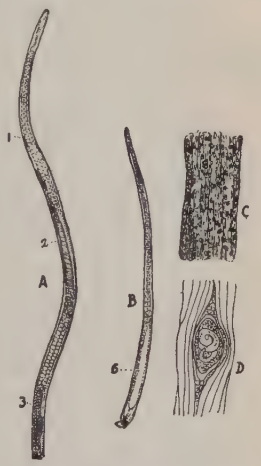

Fig. 353—*Trichinella spiralis* (from Ransom). A, female; B, male; C, a piece of pork containing cysts; D, an enlarged cyst. 1, female genital pore; 2, embryos in the uterus; 3, ovary; 4, anus; 5, testis.

3. **Trichosoma** Rudolphi. Body hair-like, the forward portion not much slenderer than the hinder; usually a single spicule present: in birds and mammals; numerous species.

T. tenuissimum Diesing. Male 10 mm. long; female 17 mm. long: in duodenum of the pigeons.

T. crassicaudum Bellingham. Female 17 mm. long; forward end rounded and with small protuberances back as far as the vulva; male 2.5 mm. long, without spicule, and lies often in the female vulva: in the liver and other organs of the rat.

Family 6. STRONGYLIDAE.

Mouth surrounded by several papillae; no œsophageal bulb; hinder end of male expanded to form a broad bursa (Fig. 355, B), also with 1 or 2 spicules: numerous genera and species which live in the intestine, lungs and other organs of vertebrates, especially mammals.

* See "Trichinosis in Germany," by C. W. Stiles, Bull. No. 30, Bureau of An. Ind., U. S. Dept. of Ag., 1901.

Key to the genera of *Strongylidae* here described:

a_1 Bursa well developed.
  b_1 Bursa without ribs; 1 spicule.....1. DIOCTOPHYME
  b_2 Bursa with ribs; 2 spicules.
    c_1 Mouth small, without teeth.
      d_1 Male and female not permanently attached.....2. DICTYOCAULUS
      d_2 Male and female permanently joined together.....3. SYNGAMUS
    c_2 Mouth large, with teeth.
      d_1 Without oral glands.
        e_1 Without ventral teeth but with cutting plates.....4. NECATOR
        e_2 With ventral teeth.....5. ANCHYLOSTOMA
      d_2 Two long oral glands.....6. STRONGYLUS
a_2 Bursa small; in fishes.....7. CUCULLANUS

1. DIOCTOPHYME Collet (*Eustrongulus* Diesing). Large worms with 6 prominent oral papillae; bursa without ribs; 1 spicule present; vulva near forward end: 1 species.

D. renale (Goeze) (*D. gigas* Rudolphi) (Fig. 354). Body generally blood red; male 40 cm. long or less and 6 mm. thick; female 1 m. long or less, and 12 mm. thick; egg (Fig. 345, A) ovoid, brown, and about .068 mm. by .04 mm.: in the kidney of the dog and other domestic animals as well as rarely in man.

Fig. 354
Dioctophyme renale (from Ward).

2. DICTYOCAULUS Railliet and Henry. Mouth with 6 small papillae, bursa large with ribs and two spicules; female genital pore behind the middle: many species.

D. filaria (Rudolphi). Body white and thread-like, from 3 to 10 cm. in length; egg about .12 mm. by .06 mm.: in the bronchi of sheep and goats, causing often a dangerous bronchitis.

D. rufescens (Leuckart). Body brown and thread-like, from 18 to 35 mm. long; egg about .1 mm. by .06 mm.: in the bronchi and lungs of sheep and goats, causing often pneumonia.

3. SYNGAMUS von Siebold. Male permanently attached by the bursa to the vulva of the much larger female, which is forward of the middle, forming together a Y-shaped object; bursa ribbed: 1 species.

S. trachealis v. Sieb. Body red; male 6 mm. long; female 20 mm. long: in the trachea of fowls, causing gapes.

4. NECATOR Stiles. Head end narrower than body and curved dorsally; mouth large, opening obliquely into a chitinous buccal capsule, the dorsal portion of which is shorter than the ventral; buccal cavity has ventrally a pair of prominent semilunar cutting plates or lips and dorsally a pair of smaller lips and a conical tooth projecting into it; a large bursa with 2 long, barbed spicules: 2 species, in man and anthropoid apes.

N. americanus* (Stiles). American hookworm (Fig. 355). Male 9 mm. long; female 11 mm. long; vulva in forward half of body; eggs (Fig. 345, B) about .07 mm. long by .038 mm. broad: in the small intestine of man and the gorilla, where it moves about sucking blood, causing

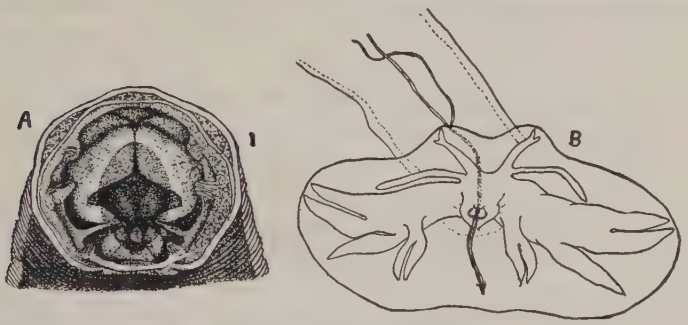

Fig. 355—*Necator americanus*. A, dorsal view of head, showing cutting lips and teeth (Looss); B, hinder end of male, showing bursa (Stiles). 1, ventral cutting lips.

often a severe ænemia; very common in the South among the poorer classes; the eggs pass out with the feces, the young worms living in the moist earth; infection may be got by drinking infected water, by eating infected substances, and even as the result of the migration of the young worms through the skin of feet or hands.

5. **Anchylostoma** Dubini. Similar to *Necator* but with head end not narrower than body and with 2 pairs of large ventral-curved teeth and a pair of dorsal teeth in place of the cutting plates, directed forwards; vulva in hinder half of body: 5 species.

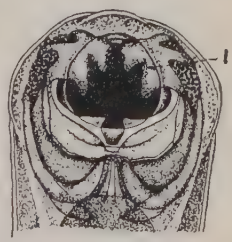

Fig. 356
Anchylostoma duodenale —dorsal view of head, showing teeth (Looss). 1, ventral teeth.

A. duodenale Dub. (Figs 345, A, and 356). Old World hookworm. Length of male 9 mm.; of female 12 mm.: in man, in Europe and Asia, occasionally in America.

A. caninum (Ercolani). Similar to the above but somewhat larger: common in dogs and cats and often fatal to young animals.

6. **Strongylus** O. F. Müller. Similar to *Anchylostoma* but with two long glands opening into the mouth, around which are small flat spines: numerous species.

* See "Report upon the Prevalence and Geographic Distribution of the Hookworm Disease in the United States," by C. W. Stiles, Bull. No. 10, Hygienic Lab., Treas. Dept., 1903. "Uncinariasis in the South," by C. A. Smith, The Jour. of the Am. Med. Asso., Vol. 41, p. 709, 1903. "The Anatomy and Life History," etc., by A. Looss, Records of School of Med., Cairo, 1911.

S. equinus Müll. The armed palisade worm. Male 20 to 30 mm. long; female 23 to 55 mm. long, 2 mm. thick; body red or brown, straight and rigid; mouth with small teeth; egg .09 by .05 mm.: common in the cæcum or colon of the horse, causing colic; the young worms live in water and moist earth and pass directly in drinking water into the horse; they are also found in the abdominal arteries where they cause aneurisms.

7. **Cucullanus** O. F. Müller. Small worms with 2 lateral chitinous plates on the head and with rudimentary bursa; mouth ridged longitudinally; male with a spicule; vulva in the middle of the body: several species.

C. elegans Zeder. Male 8 mm. long; female 13 mm. long; body yellowish or reddish; mouth with 6 papillae: in the intestine of the perch and other fish.

Family 7. ASCARIDAE.

Body often rather stout and large; mouth surrounded by 3 prominent lips, 1 dorsal and 2 ventral; œsophagus with 1 or 2 bulbs; hinder end of male spirally curved and usually 1 or 2 spicules project from the anus: several hundred species, almost all intestinal parasites in vertebrates.

Key to the genera of *Ascaridae* here described:

a_1 Large nematodes with prominent lips.....1. Ascaris
a_2 Small nematodes with usually small lips.
b_1 Male with a sucker before the anus.....3. Heterakis
b_2 No sucker present.....2. Oxyuris

1. Ascaris L. Large worms in which the 3 lips are set off by a constriction, forming a distinct knob at the front end of the body; œsophagus without distinct bulb; male with 2 equal spicules and numerous ventral caudal papillae: several hundred species, which live in the intestines of birds and mammals.

Fig. 357—*Ascaris lumbricoides* (from Braun). A, hinder end of male; B, dorsal view of front end; C, ventral view of front end.

A. lumbricoides L. Eelworm (Fig. 357). Male 15 to 25 cm. long, 3 mm. thick; female 20 to 40 cm. long, 5 mm. thick; egg (Fig. 345, C) brown, with roughened surface, about .06 mm. by .05 mm.; body with the appearance of an earth worm: in the small intestine of man and domestic animals, sometimes in considerable numbers, especially in children, when they are dangerous parasites; occasionally found in the liver, trachea, and other organs; development direct, the eggs pass out with the feces, and the young larvae develop in water or moist earth; infection is got in drinking water or from the ground or from the skin of raw fruits.

A. equorum Goeze (*A. megalocephala* Cloquet). Maw worm. Length 15 to 37 cm.; thickness 8 to 12 mm.; eggs spherical, .1 mm. in diameter: in the small intestine of the horse, often in large numbers, when it is a dangerous parasite.

Fig. 358
Ascaris canis.
Cross section showing fins (from Braun).

A. canis (Werner) (*A. mystax* Zeder) (Fig. 358). Male 6 cm. long, 1 mm. thick; female 18 cm. long; a pair of fin-like projections on the sides of the head; eggs (Fig. 345, D) almost spherical, about .07 mm. in diameter: in the intestine of cats and dogs, usually common, occasionally in man; development direct.

2. **Oxyuris** Rudolphi. Small worms in which the 3 lips are more or less indistinct; œsophagus long, with a bulb followed by a dilated portion; hinder end of male very short with but 1 spicule; vulva in forward half; hinder end of female tapering to a sharp point: about 15 species; in the large intestine of vertebrates, also in certain insects.

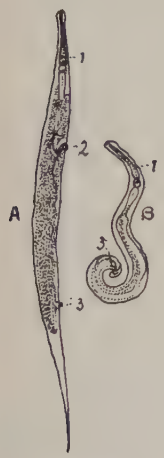

Fig. 359
Oxyuris vermicularis (from Braun).
A, female
B, male.
1, œsophagus
2, vulva; 3, anus.

O. vermicularis (L.). Pin worm (Fig. 359). Female 10 mm. long; .6 mm. thick; male 4 mm. long; a dorsal and a ventral cuticular projection on the head; egg (Fig. 345, F) .05 mm. by .02 mm.: in the large intestine, also occasionally in other parts of the digestive tract of man, especially of children; often the indirect cause of appendicitis; development direct, the eggs of the females being taken in with drinking water or directly from the hands.

3. **Heterakis** Dujardin. Lips as in *Ascaris;* male with a large sucker surrounded by 4 papillae before the anus and 2 lateral thickenings; oral papillae small: numerous species.

H. vesicularis Froehlich. Length 7 to 15 mm.; tail of male with 5 preanal and 7 postanal papillae; no teeth in mouth: in the large intestine of chickens and ducks.

H. brevicauda (Zeder). Length 5 mm.; mouth surrounded by 10 papillae: in the intestine of frogs and toads.

Class 2. GORDIACEA.*

Hair worms. Long and very slender worms of the same diameter throughout and never sharply pointed behind, which are sometimes found

* See "The Gordiacea of Certain American Collections," by T. H. Montgomery, Bull. Mus. Comp. Zool., Harvard, Vol. 32, 1898. Ibid., by the same, Pt. 2, Proc. Cal. Acad. C. Sci., 3rd Ser., Vol. 1, 1898. "Synopsis of the Gordiacea," by the same, Am. Nat., Vol. 33, p. 647, 1899.

wriggling actively in fresh-water ponds and ditches, and look much like thick horsehairs. Sometimes a number are found in a tangled mass, a feature which suggested the name of the typical genus. As larvae the worms live in the body cavity of insects, whence they migrate into the water, their sudden appearance often giving rise to the common belief that they are metamorphosed horsehairs.

The integument consists of a thick cuticula and a hypodermis, the latter being a single-layered epithelium and very different from the subcuticula of nematodes. Beneath the integument is a muscle layer consisting of a single layer of longitudinal muscle cells. The body cavity is lined with a peritoneum and traversed by dorsoventral mesenteries and is nearly filled with a mass of connective tissue cells forming a sort of parenchyma. The mouth and œsophagus in adults are closed and the intestine is a straight tube proceeding to the anus at the hinder end of the body. Special respiratory, circulatory, and excretory organs are absent.

The nervous system consists of a nerve ring round the œsophagus with two dorsal swellings and a median ventral cord. The sense organs are a pair of eyes and numerous tactile bristles. The sexes are separate; two testes and two ovaries are present and in both sexes the reproductive organs open to the outside through the anus.

Fig. 360 *Gordius* larva (Süssw. F. Deut.).

The eggs are laid in long strings in the water, the length of one observed by Leidy being 91 inches, and containing 6 million eggs. The young larvae (Fig. 360), after hatching, seeks some aquatic insect larva into which it bores its way by means of bristles on the head. It remains here in the muscles or fat body until the insect is eaten by some other water insect or fish or has completed its larval life and left the water as an adult. If in the latter case the host is eaten by a predaceous beetle the larval worm may pass into its second larval stage in its body cavity, or in a grasshopper or other insect if the first host dies and the young larva falls upon the ground. In its second host the worm grows rapidly and assumes the long hair-like form of the adult, and finally breaks its way through the body wall of its host and falls into the water or is swept there by the rain, where it becomes mature.

The class contains 2 families and about 15 American species. The second of these families is very different from the first and its relationships are rather obscure.

Key to the families of *Gordiacea:*

a_1 Fresh-water and terrestrial worms.....1. GORDIIDAE
a_2 Marine worms.....2. NECTONEMATIDAE

Family 1. GORDIIDAE.

With the characters of the order: 4 genera.

Key to the genera of *Gordiidae* here described:

a_1 Hinder end bilobed or trilobed.
  b_1 Hinder end bilobed and rolled spirally.
    c_1 Head end not obliquely truncated.....1. Gordius (male)
    c_2 Head end obliquely truncated.....2. Paragordius (male)
  b_2 Hinder end trilobed.....2. Paragordius (female)
a_2 Hinder end not forked.
  b_1 Hinder end rolled spirally.....3. Chordodes (male)
  b_2 Hinder end not rolled spirally.
    c_1 Hinder end not swollen.....1. Gordius (female)
    c_2 Hinder end swollen and knob-like.....3. Chordodes (female)

1. Gordius L. Hair worms with a forked and spirally rolled tail and often a V-shaped ridge behind the anus in the male, and a straight, unforked tail in the female: about 10 species.

G. aquaticus L. (*G. robustus* Leidy) (Fig. 361). Length 28 to 89 cm.; thickness .5 to 1 mm.; color white or brown; ends blunt; V-shaped postanal ridge in male: cosmopolitan.

Fig. 361

Fig. 362

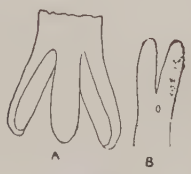

Fig. 363

Fig. 361—*Gordius aquaticus;* hinder end of male (Montgomery). Fig. 362—*Gordius lineatus;* hinder end of male (Montgomery). Fig. 363—*Paragordius varius;* hinder end of female (A) and male (B) (Montgomery).

G. lineatus Leidy (Fig. 362). No distinct V-shaped ridge behind the anus, on each side of which in the male is a longitudinal line of hairs; color yellowish-white; female with longitudinal rows of cuticular areoles: eastern states.

2. Paragordius* Camerano. Hair worms with a forked and spirally rolled tail in the male, and a trilobed tail in the female: 1 species.

P. varius (Leidy) (Fig. 363). Length 10 to 30 cm.; head of male obliquely truncated; the commonest gordian: occasionally occurs in human digestive tract; North America.

3. Chordodes Möbius. Hair worms with the hinder end spirally rolled and not forked in the male, but not rolled and with a knob-like posterior swelling in the female: 5 species.

* See "Observations on the Natural History of the Gordiacea," by J. Leidy, Proc. A. N. S., Phila., Vol. 5, p. 262. "The Adult Organization of Paragordius varius Leidy," by T. H. Montgomery, Zool. Jahrb., Vol. 18, p. 387, 1903.

C. morgani Montgomery (Fig. 364). Length 6 to 22 cm.; color brown; head white: eastern states.

Family 2. NECTONEMATIDAE.

Marine worms with body faintly ringed externally and with 2 rows of fine bristles on each side; anus absent; tail of male curved ventrally and ends with a conical projection: 1 genus and species, which is found swimming at the surface of the sea.

Fig. 364 *Chordodes morgani;* hinder end of female (Montgomery).

Nectonema Verrill. With the characters of the family.

N. agile* Verr. (Fig. 365). Length of male 5 to 20 cm.; of female 3 to 6 cm.; thickness .3 to 1 mm.; color grayish-white: marine, and pelagic at Newport, R. I., and Woods Hole; Naples; the larval form parasitic in small crustaceans (*Palæmonetes*).

Fig. 365 *Nectonema agile* (Ward).

Class 3. ACANTHOCEPHALA.†

Elongated, parasitic worms which live as adults in the intestine of vertebrates, to the walls of which they attach themselves by means of a retractile proboscis armed with hook-like spines, and as larvae in the bodies of small invertebrates, especially crustaceans.

The body of the adult may be divided into three regions, the proboscis, the neck, and the trunk. The proboscis is a more or less cylindrical structure at the front end of the body provided with several rows of recurved spines. The neck is a continuation of the proboscis, but is without spines and is sharply set off from the trunk. The trunk forms the principal part of the body and is usually smooth, but may be annulated or spinose. The integument consists of a cuticula and a subcuticula; in the latter is a network of fibers and also large spaces of lacunae, and beneath it are circular and longitudinal muscle fibers. A large body cavity is present. Extending backwards from the base of the proboscis in most forms is the proboscis sheath, a muscular sac into which the proboscis can be invaginated and thus retracted. In certain forms, however, the sheath is inserted near the middle or forward end of the proboscis, in which case it can be only partially retracted or not at all. Extending backwards from the base

* See "On Nectonema agile Verrill," by H. B. Ward, Bull. Mus. Comp. Zool., Vol. 23, p. 135, 1892.

† See "Geschichte und Ergebnisse der Echinorhynchen Forschung," etc., by M. Lühe, Zool. Annalen, Vol. 1, p. 139. "Acanthocephalen," by M. Lühe, Süsswasserfauna Deutschlands, Heft 16, 1911.

of the neck is a pair of long projections of the subcuticula called the lemnisci, the function of which is not known. The excretory system consists of a pair of nephridia which unite and open into the reproductive duct. The nervous system consists of a central ganglion in the proboscis sheath and two main nerves which run backwards; no special sense organs are present. No digestive tract is present.

The *Acanthocephala* are unisexual. Extending back from the proboscis sheath is a prominent band-like structure called the ligament which ends in the hinder part of the body cavity. In the male two ovoid testes are connected with the ligament, the vasa deferentia, with which several glands are joined, passing back to the complex genital opening at the hinder end of the body. In the female the ovary is also in the ligament; the ova escape into the body cavity whence they pass through an oviduct of complicated structure to the external opening at the hinder end of the body. Fertilization takes place in the body cavity and the embryonic development takes place there. The eggs then pass out and in order to develop farther must be swallowed by a crustacean or insect. The larval worm then bores through the intestinal wall of this intermediate host and encapsules itself in the body cavity, where it remains until the intermediate host is swallowed, probably usually in drinking water, by the final host, to the intestinal wall of which it fastens itself. The class contains 4 families, 12 genera, and over 100 species.

Family 1. ECHINORHYNCHIDAE.

With the characters of the order: several genera.

1. Echinorhynchus O. F. Müller. Body smooth, although often wrinkled after death: numerous species.

E. anguillae Müll. (Fig. 366). Body orange-colored, 6 to 29 mm. long; proboscis with 8 or 10 rows of hooks; neck long: in numerous fresh-water fish; common; Europe; larva probably in *Gammarus* and small fishes.

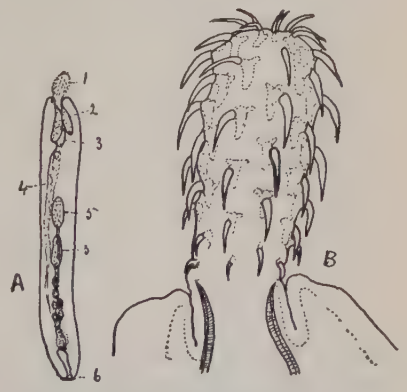

Fig. 366—*Echinorhynchus anguillae* (Süssw. F. Deut.). A, entire worm: 1, proboscis; 2, lemnisci; 3, proboscis sheath; 4, ligament; 5, testis; 6, genital pore; B, proboscis.

E. ranae Schrank. Body 5 to 60 mm. long; proboscis with 12 to 20 rows of hooks: in frogs, toads, and salamanders; common; Europe; larva in *Asellus*.

Family 2. GIGANTORHYNCHIDAE.

Body large, and annulated; lemnisci long and twisted: 1 genus.

Gigantorhynchus Hamann. With the characters of the family: 1 species.

Fig. 367
Gigantorhynchus gigas (Ward).
A, female
B, male.

G. hirudinaceus (Pallas) (*G. gigas* Block) (Fig. 367). Body white, tapering posteriorly, proboscis almost spherical and with 6 rows of 8 hooks each; male 6 to 9 cm. long and 4 mm. thick; female up to 50 cm. long and 4 to 9 mm. thick: in the intestine of pigs and often a common and dangerous parasite; the intermediate host a beetle grub, which pigs often eat.

Subphylum 3. TROCHELMINTHES.

Minute, aquatic animals which in structure bear a close relation to the trochophore larva of the annelid worms and mollusks. The body is unsegmented and often externally annulated or ringed and is never completely ciliated, although in most of them groups of cilia occur in certain regions. A spacious body cavity is present, which is not however limited by a peritoneum. The *Rotifera,* by far the largest of the three classes, are characterized by the ciliated disc-like front end of the body and usually also the forked organ of attachment at the hinder end. The other two classes comprise a few species of peculiar microscopic worms which are often included among the *Rotifera,* but which lack the anterior disc and differ from them also in other important respects. The subphylum contains 3 classes.

Key to the classes of *Trochelminthes:*

a_1 External cilia present.
  b_1 Anterior ciliated disc present.....1. Rotifera
  b_2 Ventral surface only ciliated.....2. Gastrotricha
a_2 External cilia absent.....3. Kinorhyncha

Class 1. **ROTIFERA.***

Rotifers or wheel animalcules (Fig. 379). Microscopic, aquatic animals, the body of which is composed of three divisions, the head, the trunk, and the foot. The head bears the corona, which is a ciliated disc forming

* See "The Rotifera or Wheel Animalcules," by C. T. Hudson and P. H. Gosse, 1889. "The Rotifera of Sandusky Bay," by D. S. Kellicott, Proc. Am. Mic. Soc., Vol. 18, p. 155, 1896. "The Rotifera of Sandusky Bay," by same. Ibid., Vol. 19, p. 43, 1897. "Rotatoria of the United States," by H. S. Jennings, Bull. U. S. Fish. Com. for 1899, p. 67, 1900. "Synopsis of the Rotatoria," by same, Am. Nat., Vol. 35, p. 725. "Die Süsswasserfauna Deutschlands," Heft 14, 1912. "Index of the Rotatoria," by H. K. Harring, Bull. 81, U. S. Nat. Mus., 1913.

the front end of the body and in the middle of which is the mouth, and the special sense organs. The cilia are evenly distributed over the corona in the most primitive rotifers; in others the corona is variously lobed and the cilia are in groups and usually confined to the margin and the area just within the margin. These marginal cilia in numerous common rotifers whirl in opposite directions on the two sides of the corona and resemble revolving wheels, giving the group its name. The special sense organs, when present, consist of one to three eyes and one to four tentacles. The trunk is in many rotifers encased in a shell called the lorica which is the thickened cuticula; it is often provided with spines and other projections. The foot forms the hinder portion of the body: it is usually retractile and in most rotifers ends with one, two, or several toes. Glands are present in it which secrete an adhesive substance by means of which the animal can attach itself temporarily.

The mouth opens into a large muscular pharynx called the mastax in which are paired jaws or trophi, the working of which is a noticeable feature in rotifers. In some rotifers (*Stephanops*) the pharynx is thrust out of the mouth and used as a proboscis to take in food. A narrow œsophagus joins the pharynx with the large stomach, which has a pair of large gastric glands and is joined with the dorsal anus by the short intestine. In some forms the intestine ends blindly, there being no anus. The nervous system consists of a brain dorsal to the pharynx and nerves extending from it; a subœsophageal ganglion is present in some forms. A pair of kidney tubules which contain flame cells open into a contractile bladder, the vacuole, which communicates with the hinder end of the intestine. The sexes are distinct. The males are small and without digestive organs and usually much less numerous than the females; in many species they have not been found at all. The female has usually a single small ovary and a large yolk gland which are joined with the cloaca by an oviduct, the lower end of which acts as a uterus and retains the young, in a large number of species, during development, so that they are born alive. The females reproduce parthenogenetically: at certain times, however, males are born and the fertilized eggs then produced are called "winter" or resting eggs and can resist cold and drought. Budding and fission do not occur.

Habits and Distribution.—The majority of rotifers are solitary, free-living animals, although a few species are sessile, living in tubes composed of their own secretions or of foreign matters, and a few are colonial. They are typically fresh-water animals and are everywhere abundant, but a few species are marine. They are also usually rather rigidly confined to certain environments, some living among plants and some being pelagic. Most of the common species are cosmopolitan in their distribution. Some

rotifers and their eggs can withstand desiccation many years when taken from the water and are often blown great distances by the wind or carried on the feet of birds. The food of most forms consists of minute plants and animals, but a few species are parasitic.

History.—Rotifers have been known since the time of Leeuwenhoek, who discovered them in 1703. O. F. Müller in 1786 gave those known at his time binominal names, classifying them with the *Infusoria*. Ehrenberg, in his epoch-making work on *Infusoria* published in 1838, described great numbers of rotifers and laid the foundation of the present classification. Wiegmann in 1832 had, however, already removed them from the *Infusoria* and placed them among the worms. The monograph of Hudson and Gosse contains the modern classification of the group.

About 850 species of *Rotifera* are known, of which about 250 occur in this country. They are grouped in 3 orders.

Key to the orders of *Rotifera:*

a_1 Sessile or colonial and usually tubicolous (except *Trochosphæra*). ..... 1. RHIZOTA

a_2 Free-swimming; not tubicolous and non-colonial rotifers.
b_1 Rotifers which creep like a leech, but can also swim ..... 2. BDELLOIDA
b_2 Rotifers which do not creep but swim ..... 3. PLOIMA

ORDER 1. RHIZOTA.

Usually sessile rotifers living in tubes composed of a transparent secretion or of fecal or other substances; some forms are colonial and a few are free-swimming: 3 families.

Key to the families of *Rhizota* here described:

a_1 Corona with prominent non-vibratile cilia usually on lobes; vibratile cilia very small ..... 1. FLOSCULARIIDAE
a_2 Corona without non-vibratile cilia; colonial or not ..... 2. MELICERTIDAE

FAMILY 1. FLOSCULARIIDAE.*

Solitary, sessile, or free-swimming rotifers living in a transparent tube; corona lobed in most cases and bearing groups of long, often non-vibratile cilia; vibratile cilia few, about the mouth: 3 genera.

Key to the genera of *Flosculariidae* here described:

a_1 Lobes of corona knobbed or blunt, or absent ..... 1. FLOSCULARIA
a_2 Lobes long and pointed ..... 2. STEPHANOCEROS

1. **FLOSCULARIA**† Oken. Body in a transparent tube; corona with 3 to 5 lobes, or not lobed, and bearing long non-vibratile cilia; the young of all and the adults of certain species free-swimming: about 30 species.

* See "On the Morphology of the Rotatorian Family Flosculariidae," by T. H. Montgomery, Jr., Proc. Acad. Nat. Sci., Phila., 1903, p. 363.

† See "On Floscularia Conklini Nov. Spec., with a Key for the Identification of the Known Species of the Genus," by T. H. Montgomery, Jr., Biol. Bull., Vol. 5, p. 233, 1903.

F. ornata Ehrenberg. Lobes 5, each with a round knob which bears the cilia; foot about twice as long as the body; no eyes; length .5 mm.: common and sessile; among water plants.

Fig. 368
Floscularia campanulata (Montgomery).

F. campanulata Dobie (Fig. 368). Lobes 5, distinct and not knobbed; cilia non-vibratile on entire margin of the bell-shaped corona; sessile; length .6 mm.: often common.

F. pelagica Rousselet. Corona circular, but slightly lobed with short, non-vibratile cilia; free-swimming.

2. Stephanoceros Ehrenberg. Lobes 5, very long, slender, and pointed, the cilia on them being non-vibratile and in rows or whorls; tube transparent; foot very long: 1 species.

Fig. 369
Stephanoceros fimbriatus (Montgomery).

S. fimbriatus (Goldfuss) (*S. eichhornii* Ehr.) (Fig. 369). Length 1.5 mm.: on aquatic plants; not common.

Family 2. MELICERTIDAE.

Colonial or not; usually tubicolous; corona 2 or 4-lobed with a continuous row of large marginal cilia; 1 to 3 antennae, 1 dorsal and 2 ventral: 10 genera.

Key to the genera of *Melicertidae* here described:

a_1 Non-colonial rotifers.
  b_1 Corona distinctly 2 or 4-lobed.
    c_1 Corona 4-lobed.....1. Melicerta
    c_2 Corona 2-lobed.....2. Limnias
  b_2 Corona oval or nearly circular and indistinctly 2-lobed. 3. Œcistes
a_2 Colonial rotifers.
  b_1 Colonies sessile, tubicolous or not.
    c_1 Not tubicolous.....4. Megalotrocha
    c_2 Animals in transparent tubes.....5. Lacinularia
  b_2 Colonies free-swimming, animals tubicolous. 6. Conochilus

Fig. 370
Melicerta ringens (from Süssw. F. Deut.).

1. Melicerta Schrank. Corona large, with 4 large lobes; 3 antennae, 1 minute dorsal and 2 larger ventral ones: 4 species.

M. ringens Schrank (Fig. 370). Tube formed of spherical pellets; length .8 mm.: common on water plants.

M. melicerta (Ehrenberg). Tube gelatinous; length 1 mm.; ventral antennae very long: on water plants.

2. Limnias Schrank. Corona broad, with 2 lobes; tube membranous, often roughened by dirt and sometimes annulated; antennae as in *Melicerta:* 3 species.

L. ceratophylli Schrank (Fig. 371). Tube not annulated; length 1 mm.; ventral antennae short: on water plants; abundant.

Fig. 371 *Limnias ceratophylli* (from Süssw. F. Deut.).

L. annulatus Bailey. Tube annulated; body with 5 horn-like dorsal processes; length 1 mm.

3. **Œcistes** Ehrenberg. Corona a wide oval; lobes indistinct; tube irregular or absent; dorsal antenna minute or absent: 10 species.

O. crystallinus Ehr. Tube variable, transparent, often covered with dirt; ventral antennae small, wide apart; length .5 mm.

O. melicerta (Ehr.). Two long dorsal projections just below the corona, sometimes antler-like; tube formed of pellets and very short, or wanting: common.

4. **Megalotrocha** Ehrenberg. Colonial and sessile, each colony appearing to the eye as a grayish ball; not tubicolous; corona broad, reniform; antennae inconspicuous: 2 species.

Fig. 372 *Megalotrocha alboflavicans* (from Süssw. F. Deut.).

M. alboflavicans* Ehr. (Fig. 372). Four opaque warts in a row just beneath the corona; length 2 mm., of colony 5 mm.

5. **Lacinularia** Schweigger. Colonial and similar to *Megalotrocha* but each individual is in a transparent tube: 1 species.

Fig. 373 *Conochilus unicornis* (from Süssw. F. Deut.).

L. socialis (Pallas). Length 2 mm., of colony 3 mm.: on water plants; less common than above.

6. **Conochilus** Ehrenberg. Free-swimming pelagic colonies, each individual in a transparent tube: 3 species.

C. volvox Ehr. Colony spherical, consisting of 10 to 40 individuals arranged radially; ventral antennae separate except at base; length .6 mm., of colony 1 mm.: common.

C. unicornis Rousselet (Fig. 373). Colony irregular, containing few individuals; a single large ventral antenna situated on the corona: common.

Order 2. BDELLOIDA.

Non-tubicolous rotifers (with a few exceptions) which swim with the corona and creep like a leech by attaching alternately the front and hind ends of the body; body cylindrical, with a cuticula composed of rings which can be telescoped; foot usually ending with 3 toes and with

* See "The Formation of New Colonies of the Rotifer Megalotrocha alboflavicans Ehr.," by F. M. Surface, Biol. Bull., Vol. 11, p. 182.

2 or 4 spurs a little way up; a dorsal proboscis behind the corona; ovaries 2: 2 families.

Family PHILODINIDAE.

Corona composed of 2 circular and separated retractile lobes, making 2 distinct wheels; proboscis and tentacle present: 4 genera.

Key to the genera of *Philodinidae* here described:

a_1 Two eyes present.
b_1 Eyes on the proboscis.....1. Rotifer
b_2 Eyes on neck, directly over the brain and the jaws.....2. Philodina
a_2 Eyes absent.....3. Callidina

1. Rotifer Schrank. Body long and slender and very retractile: among plants and dirt: 9 species.

R. vulgaris Schrank (Fig. 374). Body whitish and opaque, gradually tapering to the foot, which makes up half the animal; spurs not twice as long as width of body; length .5 mm.: common; also in salt water.

R. tardigradus Ehrenberg. Body dark brown in color, long and slender; spurs 3 times as long as the width of body where attached; length .8 mm.: common.

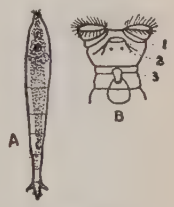

Fig. 374
Rotifer vulgaris (Süssw. F. Deut.).
A, the animal.
B, head end.
1, proboscis
2, eyes
3, tentacle.

2. Philodina Ehrenberg. Body rather thick, fusiform; 2 red eyes behind the proboscis; often in infusions: 6 species.

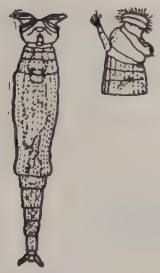

Fig. 375
Philodina roseola (from Süssw. F. Deut.).

P. aculeata Ehr. Dorsal surface of body beset with strong spines; length .5 mm.: common.

P. roseola Ehr. (Fig. 375). Body rather slender and often rose-colored; foot not distinctly set off; length .5 mm.: common.

3. Callidina Ehrenberg. Body elongate, without eyes, the jaws often with fine transverse ridges: many species.

C. elegans Ehr. Each jaw with 10 ridges, cuticula smooth; length .35 mm.: common in infusion.

Order 3. PLOIMA.

Non-tubicolous rotifers, which swim and do not creep like a leech, but may creep with the toes or may leap; some are parasitic: 2 suborders.

Key to the suborders of *Ploima:*

a_1 Without shell (lorica).....1. Illoricata
a_2 With lorica.....2. Loricata

Suborder 1. ILLORICATA.

Ploimate rotifers with a flexible cuticula and no shell (lorica): 6 families.

Key to the families of *Illoricata* here described:

a_1 No foot present; animals transparent, short and more or less spherical.
b_1 Animals spherical with a ring of cilia near equator....1. TROCHOSPHÆRIDAE
b_2 Body sac-shaped.
c_1 No long lateral appendages.....2. ASPLANCHNIDAE
c_2 Long lateral appendages present with which the animal jumps.
3. TRIARTHRIDAE

a_2 Foot with 2 toes present.
b_1 Corona with 3 to 7 large prominences with setae.....4. HYDATINIDAE
b_2 Corona without these; body elongate, often with a pair of ciliated projections (auricles).....5. NOTOMMATIDAE

FAMILY 1. TROCHOSPHÆRIDAE.

Spherical rotifers without corona or foot and with an encircling band of cilia near the equator or towards the forward pole; mouth ventral and anus at the hinder pole; the viscera are in the hinder hemisphere: 1 genus.

TROCHOSPHÆRA Semper. With the characters of the family: about 3 species.

T. solstitialis Thrope (Fig. 376). Band of cilia between equator and forward pole; diameter 2 mm.: in the Illinois River and at Put-in-Bay, Lake Erie; Asia.

FAMILY 2. ASPLANCHNIDAE.

Large transparent sac-shaped rotifers, without anus and usually pelagic: 3 genera.

1. ASPLANCHNA Gosse. Foot absent; jaws large; animals vivipa-

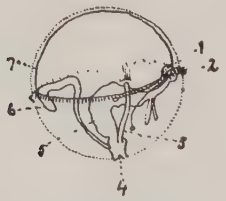

Fig. 376

Fig. 377

Fig. 378

Fig. 376—*Trochosphæra solstitialis* (Delage et Hérouard). 1, brain; 2, mouth; 3, kidney tubule; 4, anus; 5, intestine; 6, ovary; 7, dorsal nerve. Fig. 377—*Asplanchna herricki* (from Süssw. F. Deut.). Fig. 378—*Polyarthra platyptera* (from Süssw. F. Deut.).

rous, the embryo being frequently seen in the mother; 1 or 3 eyes present; corona with two slight elevations: about 7 species.

A. priodonta Gosse. Body without humps and barrel-shaped; eyes 3; length .5 mm.: often very common; pelagic.

A. herricki* De Guerne (Fig. 377). Body amphora-shaped and without humps; eyes 3: pelagic.

* See "Early Development of Asplanchna herrickii," by H. S. Jennings, Bull. Mus. Comp. Zool., Vol. 30, 1896.

2. **Asplanchnopus** De Guerne. Foot present; animals viviparous: 2 species.

A. multiceps Schrank. Foot small; length 1 mm.: pelagic.

Family 3. TRIARTHRIDAE.

Foot absent; long paired appendages at the side by means of which the animal skips or swims and which may give it the appearance of a crustacean: several genera.

Polyarthra Ehrenberg. Body rectangular with 12 long blade-shaped appendages with serrate edges arranged in 4 groups: 1 species.

P. platyptera Ehr. (Fig. 378). One eye present; length .15 mm.: very common both at surface and bottom.

Family 4. HYDATINIDAE.

Body cylindrical or sac-shaped with a short foot which has 2 small toes; corona with a number of elevations bearing setae: 5 genera.

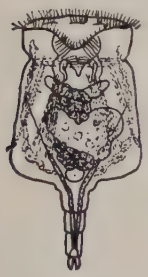

Fig. 380
Notops brachionus (from Süssw. F. Deut.).

1. **Hydatina** Ehrenberg. Without eyes, but with a tentacle: 8 species.

H. senta* Ehr. (Fig. 379). Body large, .5 mm. long, transparent: often common.

2. **Notops** Hudson. Single eye present; corona large with a ring of cilia and bearing several large prominences crowned with setae: several species.

N. brachionus (Ehrenberg) (Fig. 380). Body large, quadrangular and transparent; foot half as long as body and little retractile; length .5 mm.: often common.

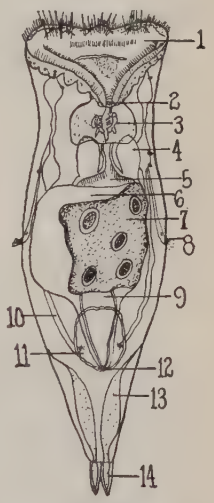

Fig. 379
Hydatina senta (Süssw. F. Deut.).
1, corona; 2, mouth; 3, mastax; 4, gastric gland; 5, stomach; 6, ovary; 7, yolk gland; 8, lateral sense organ; 9, intestine; 10, kidney tubule; 11, vacuole; 12, anus; 13, adhesion glands; 14, toes.

Family 5. NOTOMMATIDAE.

Body soft and elongate; corona oblique in position, without lobes, and covered with cilia and often with a pair of lateral ciliated projections called auricles: 15 genera.

* See "Studies in the Life Cycle of Hydatina senta," by A. F. Shull, Jour. Ex. Zool., Vols. 8, 10, and 12, 1910-1912. "The Influence of Food in Controlling Sex in Hydatina senta," by D. D. Whitney, same, Vol. 17, 1914.

Key to the genera of *Notommatidae* here described:

a_1 Auricles present.
  b_1 Body not conspicuously annulated.
    c_1 Very large rotifers with 3 or 5-lobed brain.....1. COPEUS
    c_2 Not large and brain not lobed.....2. NOTOMMATA
  b_2 Body conspicuously annulated.....3. TAPHROCAMPA
a_2 Auricles absent.
  b_1 Toes minute.....4. PROALES
  b_2 Toes conspicuous.....5. FURCULARIA

1. COPEUS Gosse. Large rotifers, slow-moving, usually enlarged behind the middle; brain 3-lobed; body projects backward from the foot, forming a tail; auricles present: 7 species; vegetable feeders.

C. pachyurus Gosse (Fig. 381). Tail rounded and thick; auricles large; brain 3-lobed; foot 2-jointed; length .33 mm.

Fig. 381

Fig. 382

Fig. 383

Fig. 381—*Copeus pachyurus* (from Süssw. F. Deut.). Fig. 382—*Notommata tripus* (Süssw. F. Deut.). Fig. 383—*Taphrocampa annulosa* (Süssw. F. Deut.).

2. NOTOMMATA Ehrenberg. Small rotifers with an elongate body and auricles; tail usually present; foot and toes usually small: many species; among water plants.

N. tripus Ehr. (Fig. 382). Tail as long as the toes, the animal appearing to end behind in 3 toes; length .1 mm.

N. truncata Jennings. Body red in color, long and truncate at each end; cilia extending on to ventral surface; foot very small.

3. TAPHROCAMPA Gosse. Body small and with numerous permanent annulations; small tail just above the foot: 4 species.

T. annulosa Gosse (Fig. 383). Minute rotifer with a cylindrical body and with a pair of small auricles; length .1 mm.

Fig. 384 *Furcularia forficula* (Süssw. F. Deut.).

4. PROALES Gosse. No auricles or tail present; toes inconspicuous; body small and cylindrical: 8 species.

P. sordida Gosse. Body thick; head broad, with an eye; foot very broad; toes conical; length .22 mm.

5. FURCULARIA Ehrenberg. Auricles absent; body cylindrical or bulging in the middle; toes conspicuous; eye red at apex of head: 12 species.

F. forficula Ehr. (Fig. 384). Body cylindrical, with straight sides and .35 mm. long: abundant.

Suborder 2. LORICATA.

Lorica present, usually much flattened: 12 families.

Key to the families of *Loricata* here described:

a_1 Foot absent.....1. Anuræidae
a_2 Foot present.
b_1 Foot transversely wrinkled or ringed (not jointed).
c_1 Foot ending in a ciliated cup, without toes.....2. Pterodinidae
c_2 Foot ending in 2 toes.....3. Brachionidae
b_2 Foot not wrinkled or ringed, often jointed, with 1 or 2 toes.
c_1 Toes not long and spine-like.
d_1 Foot jointed; lorica without dorsal spines.....3. Brachionidae
d_2 Head with a chitinous covering like the visor of a cap; foot and toes often very long; 1 eye.....4. Dinocharidae
c_2 Foot usually very short and ending in 1 or 2 slender and usually long toes; lorica usually flattened and ovate.
d_1 No arched shield over head.
e_1 Toes very slender and bristle-like, often very long.....5. Rattulidae
e_2 Toes 1 or 2 in number, slender and rod-shaped.....6. Cathypnidae
e_3 Toes 2 in number, long and diverging.....7. Euchlanidae
d_2 An arched shield over head.....8. Coluridae

Family 1. ANURÆIDAE.

Foot absent; lorica usually with 6 long spine-like projections at its anterior margin and 1 or 2 at its posterior: 3 genera.

Anuræa Ehrenberg. Lorica thick walled and opaque, marked with polygonal areas on its dorsal surface; empty loricas frequently found: 7 species.

A. cochlearis Gosse. Lorica prolonged posteriorly into a long spine, which, however, may be wanting; length .16 mm.

A. aculeata Ehr. (Fig. 385). Lorica quadrangular with a spine at each of the postero-lateral angles; .15 mm. long.

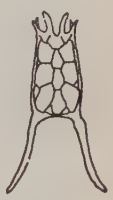

Fig. 385 *Anuræa aculeata* (Süssw. F. Deut.).

Family 2. PTERODINIDAE.

Foot cylindrical and transversely wrinkled or annulated; body very retractile: 2 genera.

Pterodina Ehrenberg. Lorica flattened; a pair of lateral semicircles of cilia on the corona; 2 eyes; foot ending in a ciliated cup: 3 species.

P. patina Ehr. (Fig. 386). Lorica very transparent, flat and circular and .17 mm. long, without teeth: common among algae.

Family 3. BRACHIONIDAE.

Foot long, cylindrical, and usually not jointed, but annulated or wrinkled, with 2 toes; lorica squarish and flattened and usually with spine-like projections from its anterior margin: 3 genera.

1. **Brachionus** Pallas. Lorica arched dorsally, flattened ventrally; 1 red eye: numerous species, some marine.

B. rubens Ehrenberg (Fig. 387). Six straight spines on anterior margin; no posterior spines; color pinkish: often common.

B. bakeri O. F. Müller. Six spines on anterior margin, the 2 middle ones curving outward; 2 lateral spines on posterior margin may be long, short, or absent; length .25 mm.: often very common.

Fig. 386

Fig. 387

Fig. 388

Fig. 386—*Pterodina patina* (Süssw. F. Deut.). Fig. 387—*Brachionus rubens* (Süssw. F. Deut.). Fig. 388—*Noteus quadricornis* (Süssw. F. Deut.).

B. militaris Ehr. Foot jointed; lorica with 10 anterior and 4 posterior spines, its surface facetted and covered with raised points; length .25 mm.

2. **Noteus** Ehrenberg. Foot jointed; lorica oval and with 2 anterior and 2 posterior spines; no eye: 1 species.

N. quadricornis Ehr. (Fig. 388). Dorsal surface facetted, whole surface roughened; length .35 mm.

Family 4. DINOCHARIDAE.

Fig. 389 *Scaridium longicaudum* (Süssw. F. Deut.).

Lorica more or less cylindrical and usually with an anterior dorsal projection over the head; foot very long with 2 long toes: 4 genera.

1. **Scaridium** Ehrenberg. Lorica vase-shaped, smooth, and transparent, without the dorsal projection; 1 eye; foot and toes very long: several species.

S. longicaudum (O. F. Müller) (Fig. 389). Body cylindrical; toes and foot longer than the rest of the body; .4 mm. long.

2. **Stephanops** Ehrenberg. Head covered with a large semicircular shield; foot and toes not usually long; 1 to 3 long movable spines project from the back: several species.

S. longispinatus Tatem. One long spine from the middle of back; length .15 mm.

Family 5. RATTULIDAE.*

The very short foot ends in one or more slender, often very long, bristle-like toes; lorica more or less cylindrical; 1 eye: 2 genera and 35 species.

1. Rattulus Lamarck. One long toe, often as long as the rest of the body; a short toe also usually present which is not a third the length of the long toe: 20 species.

Fig. 390
Rattulus longiseta (Süssw. F. Deut.).

R. longiseta (Schrank) (*R. bicornis* Ehrenberg) (Fig. 390). Two spines of unequal length at the anterior margin of the lorica; toe two-thirds the length of the body; length .5 mm.: common.

R. mucosus Stokes. Lorica with 2 parallel ridges close together for half its length; body ovoid: length .2 mm.: often common.

2. Diurella Bory de St. Vincent. Two toes present of equal length or one more than a third the length of the other: 14 species.

Fig. 391
Diurella tigris (Jennings).

D. tigris (O. F. Müller) (Fig. 391). Toes equal and long; body cylindrical, .2 mm. long with a tooth on anterior margin of the lorica: very common in aquatic vegetation in quiet water.

D. porcellus (Gosse). Toes slightly unequal, folded under the body, which is short, curved, and .15 mm. long; lorica with 2 marginal teeth: very common.

Family 6. CATHYPNIDAE.

Body broad; dorsal plate convex, ventral plate flat, the 2 plates separated by a deep groove on each side; foot very short with 1 or 2 rod-shaped toes; 1 eye: 3 genera.

1. Cathypna Gosse. Lorica oval or nearly circular; 2 toes: 3 species.

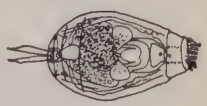

Fig. 392
Cathypna luna (Süssw. F. Deut.).

C. ungulata Gosse. Body large, being .3 mm. long, including toes; dorsal plate projecting over the foot; toes half as long as lorica: often very common.

C. luna (O. F. Müller) (Fig. 392). Toes two-fifths as long as lorica; each with a distinct shoulder at side near the tip; length .2 mm.: often common.

2. Monostyla Ehrenberg. Body oval or nearly circular, with 1 rod-like toe: 10 species.

* See "The Rotatoria of the United States, II; a Monograph of the Rattulidae," by H. S. Jennings, Bull. U. S. Fish. Com., Vol. 22, p. 273, 1903.

M. bulla Gosse (Fig. 393). Dorsal plate very high; ventral plate somewhat convex; anterior margin with a notch; .25 mm. long: very common among aquatic plants.

Family 7. EUCHLANIDAE.

Fig. 393
Monostyla bulla (Jennings).

Large transparent rotifers with a convex dorsal and a flat or slightly convex ventral plate; foot jointed, with 2 large, diverging, blade-shaped toes: 2 genera.

Euchlanis Ehrenberg. Lorica oval and flat; eye present: 7 species.

E. dilatata Ehr. (Fig. 394). Lorica with a pair of lateral flanges projecting from its ventral plate; anterior dorsal margin with a broad gap having a straight bottom; length .3 mm.: often very common in aquatic vegetation.

Family 8. COLURIDAE.

Head surmounted by an arched shield, appearing in a side view like a hook: 5 genera.

1. **Metopidia** Ehrenberg. Lorica flattened, usually turtle-like in appearance; usually 2 eyes: 11 species.

M. lepadella Ehr. (Fig. 395). Lorica oval, without teeth or spines

Fig. 394

Fig. 395

Fig. 396

Fig. 394—*Euchlanis dilatata* (Süssw. F. Deut.). Fig. 395—*Metopidia lepadella* (Süssw. F. Deut.). Fig. 396—*Monura colurus* (Hudson and Gosse).

or prominent angles; 2 eyes; ventral plate indented behind; length .08 mm.: often abundant among aquatic plants.

M. acuminata Ehr. Lorica oval, ending behind in a sharp point; length .08 mm.: often common among aquatic plants.

2. **Monura** Ehrenberg. Lorica arched, more or less compressed laterally, often open mid-ventrally.

M. colurus Ehr. (Fig. 396). Length .1 mm.: often common among algae in the sea.

Class 2. GASTROTRICHA.*

Minute worms less than .5 mm. long with an elongated body, usually forked behind, with a ciliated ventral surface and a dorsal surface either bare or covered with bristles or scales arranged in longitudinal rows; head end contains the mouth and usually bears a pair of eyes and paired sensory bristles; digestive tract a straight tube with a long muscular œsophagus, extending to the anus, which is in the dorsal surface at the hinder end of the body; a pair of long kidney tubules opens into the intestine; a very large brain is present, dorsal to the œsophagus, from which nerves radiate; animals hermaphroditic, paired ovaries and testes being present in the hinder part of the body cavity; no genital ducts are present and it is not known how the very large eggs reach the outside; development direct: fresh-water animals found among infusorians and rotifers; about 32 species, of which 12 have been found in this country.

Family CHÆTONOTIDAE.

With the characters given above: several genera.

Key to the genera of *Chætonotidae* here described:

a_1 Posterior end forked.
  b_1 Back covered with spines or scales.
    c_1 Caudal forks short.....1. Chætonotus
    c_2 Caudal forks very long and segmented.....2. Lepidoderma
  b_2 Back not covered with spines or scales.....3. Ichthydium
a_2 Posterior end not forked.....4. Dasydytes

1. Chætonotus Ehrenberg.† *Gastrotricha* with a short, unsegmented forked tail and with dorsal spines or scales; head formed of 3 lobes, usually with 2 pairs of tufts of sensory bristles and in some species with a pair of eyes; ventral side flat: 23 species.

Fig. 397 — *Chætonotus larus* (Stokes). A, dorsal aspect; B, head.

Fig. 398 *Chætonotus longispinosus* (Stokes).

C. larus (O. F. Müller) (Fig. 397). Back covered with short conical spines, the posterior ones being usually the larger; length .12 mm.: common.

C. longispinosus Stokes (Fig. 398). Back with 2 transverse rows of long spines: often common.

2. Lepidoderma Zeller. Back covered with scales; tail forks long and segmented: several species.

L. rhomboides (Stokes) (Fig. 399). Forks of tail one-fourth the length of the body and composed of 20 segments; a deep, transverse depression back of the mouth; length .3 mm.

* See "Beiträge zur Systematic der Gastrotrichen," by T. Grünspan, Zool. Jahrb. Syst., Vol. 26, 1908. "Die Süsswasserfauna Deutschlands," Heft 14, 1912.

† See "Aquatic Microscopy," etc., by A. C. Stokes, p. 185, 1896.

3. **Ichthydium** Ehrenberg. Like *Chætonotus* except that the back is bare: several species.

I. podura (O. F. Müller) (Fig. 400). A pair of vertical spines on the neck, and another pair near the hinder end; length .07 mm.: common.

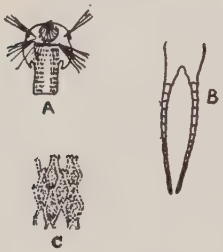

Fig. 399

Fig. 400

Fig. 401

Fig. 399—*Lepidoderma rhomboides* (Süssw. F. Deut.). A, head; B, tail; C, dorsal scales. Fig. 400—*Ichthydium podura* (Süssw. F. Deut.). Fig. 401—*Dasydytes saltitans* (Stokes).

4. **Dasydytes** Gosse. Body wide, with a distinct neck and head and no forked tail: several species.

D. saltitans Stokes (Fig. 401). Head with long cilia on both sides; neck very flexible; 2 sets of long bristles cross each other on the back; length .08 mm.: not common.

Fig. 402
Echinoderes dujardini (from Claus).

Class 3. KINORHYNCHA.*

Minute marine worms less than .5 mm. in length; body arched dorsally and concave ventrally, and composed of a series of rings; body cavity not segmented; outer surface not ciliated but provided with spines and bristles; head and neck retractile, with a ring of hooks around the mouth and a number of long locomotory spines; hinder end usually forked; paired genital pores and paired excretory pores near hinder end; sexes separate: about 30 species.

Family ECHINODERIDAE.

With the characters given above: 2 genera.

Echinoderes Dujardin. Eyes present: several species in the Mediterranean and Atlantic.

E. dujardini Claparède (Fig. 402). Body composed of 13 rings; 2 red eyes; color reddish: in mud and on algae.

* See "Zur Kenntniss der Echinoderen," by C. Zelinka, Zool. Anz., Vol. 32, p. 130, 1908.

Subphylum 4. BRYOZOA.* (Polyzoa.)

Minute and mostly colonial animals which are attached to rocks, plants, and other objects in the sea or fresh water. The colony is usually made up of hundreds or thousands of individuals which have arisen from one another by a process of budding, and is often mosslike in appearance, whence the name of the group. The *Loxosomidae* are the only non-colonial family. The individual members of a colony are called the zooids: they are more or less cylindrical in form and are often polymorphic in structure. The outer wall of the zooid is in most cases a thick cuticula secreted by a hypodermal cell layer: it is often hardened by the presence of calcium carbonate and forms a rigid case within which lie the soft parts of the animal. This case, which is called the ectocyst or zoœcium (Fig. 406, 8), will often remain long after the death of the animal and the disappearance of the soft part. In *Pectinatella* and some other forms the body wall is fleshy or jelly-like.

The soft parts of a zooid consist of the viscera and the tentacle-sheath with the tentacles which constitute the anterior end of the body. The tentacles are hollow and ciliated and are borne upon a prominent oval or horseshoe-shaped ridge called the lophophore (Fig. 406, 1).

The body wall below the tentacles is highly flexible and in the *Ectoprocta* these can be completely retracted within the zoœcium. In the center of the lophophore is the mouth and in the *Entoprocta* the anus also: in the *Ectoprocta* the anus is situated just outside of it. The tentacles are the only portion of the external surface of the *Bryozoa* that is ciliated.

The internal organs differ very much in the two great groups of the *Bryozoa* and will be described when these are presented.

Distribution and Habits.—The majority of *Bryozoa* are marine, being found from tide water to very great depths. Between tide lines and in shallow water incrusting and creeping colonies which are attached to rocks, shells, or seaweed are common, while in deeper water erect and branching colonies are the more abundant. No *Bryozoa* are parasitic, although many species live commensally with other animals or with plants. The group is a very ancient one, occurring in the Cambrian and all subsequent formations.

* See "Report upon the Invertebrate Animals of Vineyard Sound," etc., by A. E. Verrill, Rep. U. S. Com. Fish., 1871-72, p. 292. "British Marine Polyzoa," by Thomas Hincks, London, 1880. "Synopsis of North American Invertebrates, I. Freshwater Bryozoa," by C. B. Davenport, Am. Nat., Vol. 33, p. 593, 1899. "Sponges and Bryozoa of Sandusky Bay," by F. A. Landacre, The Ohio Naturalist, Vol. 1, p. 96, 1901. "The Bryozoa. Papers from the Harriman Alaska Expedition," by Alice Robertson, Proc. Wash. Acad., Vol. 2, p. 315, 1900. "The Freshwater Bryozoa of the United States," by C. B. Davenport, Proc. U. S. Nat. Mus., Vol. 27, p. 211, 1904. "The Bryozoa of the Woods Hole Region," by R. C. Osburn, Bull. Bur. Fish., Vol. 30, 1912. "The Bryozoa of Tortugas," by same, Pub. No. 182, Carn. Inst., Wash., 1914.

History.—The *Bryozoa* were thought to be seaweeds by the earlier naturalists. Linnæus grouped them with the corals and hydroids. Here they remained until 1830, when J. V. Thompson separated them from the polyps because they possess a digestive tube and called them *Polyzoa,* by which name they are still known by English and many American zoologists. In 1831 Ehrenberg performed the same service and called the new group *Bryozoa,* which is the name in use among continental and many American zoologists. In 1841 Milne-Edwards created the phylum *Molluscoidea* to include the *Bryozoa* and *Tunicata,* in which the first named group will still be found in many textbooks. The terms *Ectoprocta* and *Entoprocta* were introduced by H. Nitzsche in 1870.

About 1,700 species of marine and 35 species of fresh-water *Bryozoa* are known, which are grouped in 2 classes.

Key to the classes of *Bryozoa:*

a_1 Tentacles not retractile into the zoœcium.....1. ENTOPROCTA
a_2 Tentacles retractile.....2. ECTOPROCTA

CLASS 1. ENTOPROCTA.*

Minute, primitive *Bryozoa,* in which the anus is within the circle of the lophophore. The body consists of a calyx or head and a contractile stalk, the former containing the viscera. The lophophore is circular and supports a single row of tentacles. The depression within the lophophore, which is called the vestibule, contains the mouth and the anus (Fig. 405); projecting over the former is a lip called the epistome. The lophophore cannot be retracted into the zoœcium, but the tentacles can be rolled into the vestibule and partly covered by an integumental fold which arises at their base.

The viscera fill almost the entire space within the body. What space is left and the entire inner portion of the stem are occupied by a gelatinous parenchyma, so that a definite body cavity is wanting. The digestive tube is U-shaped, an œsophagus, stomach, and intestine being distinguishable. The genital organs consist of a pair of gonads which open into the vestibule. The animals are either unisexual or hermaphroditic: in *Loxosoma davenporti* the gonads function as ovaries first and as testes later. A pair of kidney tubules with flame cells open either into the vestibule or the rectum. The nervous system consists of a central ganglion situated between the mouth and the anus and radiating nerves.

The *Entoprocta* are found in both salt and fresh water. They are a small group comprising about 20 species, which are grouped in 3 families.

* See "Studies in Pacific Coast Entoprocta," by A. Robertson, Proc. Cal. Acad. Sci., Vol. 2, p. 320, 1900.

Key to the families of *Entoprocta:*

a_1 Solitary *Entoprocta*.....1. LOXOSOMIDAE
a_2 Colonial *Entoprocta.*
b_1 Fresh-water *Entoprocta*.....2. URNATELLIDAE
b_2 Marine *Entoprocta*.....3. PEDICELLINIDAE

FAMILY 1. LOXOSOMIDAE.

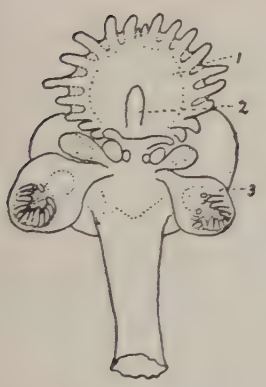

Fig. 403
Loxosoma davenporti (Nickerson).
1, lophophore; 2, rectum; 3, bud.

Solitary *Entoprocta,* which, however, often bear young buds, with 10 to 26 tentacles, with a contractile stalk at the base of which is a foot gland which is of use in attaching the animal and may be wanting in the adult animal, and with an obliquely placed lophophore: 3 genera.

LOXOSOMA Keferstein. With the characters of the family: 15 species, which are usually associated with marine annelids.

L. davenporti* Nickerson (Fig. 403). Length up to 2.4 mm.; small foot gland present; tentacles numbering from 22 to 26; from 2 to 12 buds usually present; anus elevated on a cone; mammary organ present in the floor of the vestibule to which developing embryos attach themselves to get nourishment: abundant in Vineyard Sound.

L. minuta Osburn. Body oval, .3 mm. long: on *Phascolosoma* and *Phascolion* on New England coast.

FAMILY 2. URNATELLIDAE.

Colonial, fresh-water *Entoprocta,* each colony consisting of a few zooids, which rise from a common disc; stalks long and jointed and branching: 1 genus.

URNATELLA Leidy. With the characters of the family: 1 species.

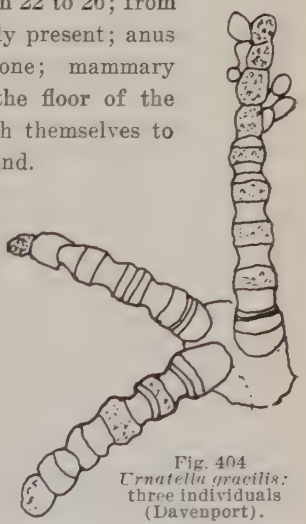

Fig. 404
Urnatella gracilis: three individuals (Davenport).

U. gracilis† Leidy (Fig. 404). Stalk up to 4 mm. long; calyx about a tenth as long and bell-shaped; usually 2 zooids in a colony: on the under side of stones in running water, in the eastern and central states.

* See "Loxosoma davenporti," by W. S. Nickerson, Jour. Morph., Vol. 17, p. 351, 1901.

† See "On Urnatella gracilis," by C. B. Davenport, Bull. Mus. Comp. Zool., Vol. 24, 1893.

Family 3. PEDICELLINIDAE.

Colonial marine *Entoprocta* in which the zooids rise from a creeping, branching stolon; the stalk is long and separated from the calyx by a diaphragm: 2 genera.

Fig. 405 *Pedicellina cernua* (altered from Osburn). 1, mouth 2, anus 3, stomach.

Pedicellina Sars. With the characters of the family: 6 species, 3 in Long Island Sound.

P. cernua (Pallas) (*P. nutans* Dalyell; *P. americana* Leidy) (Fig. 405). Calyx cup-shaped with 12 to 24 tentacles; stalk yellowish-red in color, with or without spines on stalk and calyx and tapering towards the top: on shells and algae in shallow water; Atlantic coast, from Labrador to Florida; Europe; often common.

Class 2. **ECTOPROCTA.**

Bryozoa living in large colonies, in which the anus is outside the lophophore and this structure with the tentacles can be retracted into the zoœcium (Fig. 406). The body cavity is an extensive space which is lined throughout by a peritoneum consisting either of a single layer of cells or thin layers of an irregular cellular parenchyma. In certain species the body cavities of the zooids communicate with one another. The digestive tract is a wide ciliated U-shaped tube, the aboral portion of which is the sac-shaped stomach. Joining the aboral end of the latter organ with the base of the body cavity is a mesenterial strand called the funiculus. The animals are hermaphroditic, the gonads developing in the peritoneum, the testes usually on the funiculus and the ovaries on the lateral walls. The ova and sperm, except in the fresh-water species, fall into the body cavity, where fertilization takes place. The eggs develop in the body cavity up to the larval stage in certain species, when the young animals reach the outside either through a birth opening or as the result of the disintegration of the parent. In other forms the fertilized eggs pass into special outgrowths of the body wall called oœcia or ovicells (Fig. 414, 1) and develop there. In the *Phylactolæmata* the

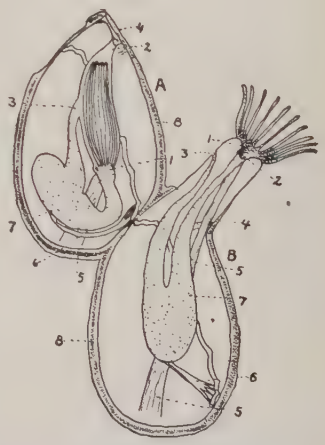

Fig. 406—Diagram of an ectoproct (Chilostomid).
A, a retracted animal; B, an extended animal (Delage et Hérouard). 1, lophophore; 2, mouth; 3, anus; 4, operculum; 5, retractile muscle; 6, funiculus; 7, digestive tract; 8, zoœcium.

embryo develops in the ovary, receiving nutriment directly from the body cavity.

All ectoprocts develop also asexually by budding, and thus produce the branching and incrusting colonies which characterize the group. In many species polymorphic zooids appear which differ much from the others in structure and perform certain specialized functions. These are the œcia, which are brood chambers, above mentioned, the avicularia (Fig. 411, A), birdhead-like structures which seize small animals in their jaws, and are probably defensive in function but also function in keeping the surface of the colony clean, and the vibracula (Fig. 411, B), whip-like appendages which wave about in the water and are also defensive. In the fresh-water *Phylactolæmata* disc-like buds called statoblasts, which have a hard chitinous shell, develop on the funiculus and either float or drop to the bottom on the death of the animal in the fall of the year or in periods of drought. In the spring or on the return of the wet season each statoblast gives rise to a young colony.

The *Ectoprocta* have great powers of regeneration. Periodically in the marine species the soft parts of the animal, with the exception of the body wall, break down and form a single round mass called the brown body. Later new organs develop, the brown body apparently being expelled from the body as waste matter.

Kidneys have not been certainly demonstrated in *Ectoprocta*. No blood vessels are present, but a blood fluid fills the body cavity. The nervous system consists of a ganglion between the mouth and anus and nerves radiating from it: in many species no nervous system has yet been seen. No special sense organs are found. The class contains 2 orders and the great majority of all *Bryozoa*.

Key to the orders of *Ectoprocta:*

a_1 Mostly marine *Ectoprocta*, with a circular lophophore....1. GYMNOLÆMATA
a_2 Fresh-water *Ectoprocta* with a horseshoe-shaped or oval lophophore.
2. PHYLACTOLÆMATA

ORDER 1. GYMNOLÆMATA.

Lophophore circular; mouth can usually be closed by a flap called the operculum; vibracula, avicularia, and œcia often present: marine *Bryozoa* (excepting the *Paludicellidae*) including about 1,700 species, which are grouped in 3 suborders.

Key to the suborders of *Gymnolæmata:*

a_1 Opening of zoœcium wide and circular and not capable of being closed by an operculum.....1. CYCLOSTOMATA
a_2 Opening of zoœcium, when lophophore is retracted, more or less flattened and capable of being closed by an operculum.
b_1 Operculum a movable horn-like valve.....2. CHILOSTOMATA
b_2 Operculum composed of a fringe of setae.....3. CTENOSTOMATA

Suborder 1. CYCLOSTOMATA.

Zoœcia tubular, in most cases densely calcareous, with a wide terminal, circular opening, and without operculum, avicularia, or vibracula: 4 families.

Key to the families of *Cyclostomata* here described:

a_1 Colony distinctly jointed, and erect.....1. Crisiidae
a_2 Colony not distinctly jointed, and either recumbent or erect.
b_1 Colony usually branching and recumbent, or more or less erect (discoid in *Diastopora*).....2. Tubuliporidae
b_2 Colony discoid.....3. Lichenoporidae

Family 1. CRISIIDAE.

Colony erect and branching, calcareous and with horn-like joints so that it is more or less flexible, with jointed and often branching root fibers given off from the base or from the internodes which serve to fasten it; zoœcia in 1 or 2 rows; tentacles 8 in number; large oœcia present: 1 genus.

Fig. 407—*Crisia eburnea* (Osburn).

Crisia Lamouroux. With the characters of the family: about 35 species.

C. eburnea (L.) (Fig. 407). Colony white in color, forming bushy tufts from 8 to 25 mm. high; zoœcia in 2 rows and alternate, slightly curved out, almost entirely adnate: cosmopolitan; common from Long Island Sound to Arctic Ocean; California; Europe; from low-water mark to 80 fathoms.

Family 2. TUBULIPORIDAE.

Colony entirely creeping and incrusted or more or less erect, either simple or branched and often radiating from a central point; zoœcia in 1 or several rows, adhering to one another laterally, with the upper end more or less free: about 5 genera.

Tubulipora Lamarck. Colony entirely recumbent or partially erect, forming a variously shaped expansion, either simple or branched; zooids tubular, arranged in divergent series: about 29 species.

Fig. 408
Tubulipora flabellaris (Osburn).

T. flabellaris (Fabricius) (Fig. 408). Colony 12 mm. in diameter, of a pale purplish color, flabellate when young, but more or less circular and lobed when old; zoœcia punctate, long, and slender, .15 mm. in diame-

ter, crowded together and radiating from the center to the edge, and with the outer ends erect: Long Island Sound to Greenland, on algae, etc., in shallow water; Europe.

T. fimbria Lamarck. Colony 12 mm. in size; fan-shaped and lobed; zoœcia slender, not raised at the outer ends, and wrinkled transversely: in shallow and deep water; North Atlantic; Europe.

T. liliacea (Pallas) (*T. pruinosa* Stimpson). Colony about 9 mm. high and white, or often purple and punctate; branches in same plane: Atlantic coast; Europe; on shells, hydroids, etc.

Family 3. LICHENOPORIDAE.

Colony discoid, flat, or more or less raised, forming either a simple disc or several confluent ones; zoœcia partially erect, forming distinct rows which radiate from a large central free area and are not close together, the spaces between being porous: 2 genera.

Lichenopora Defrance (*Discoporella* Gray). Colony thin and laminate, sometimes composite: about 30 species.

L. hispida Fleming. Single disc up to 6 mm. in diameter; each individual with 10 short tentacles: North Atlantic, on shells, algae, etc., from moderate to great depths; often common; Europe.

L. verrucaria (Fabricius). Disc 3 mm. in diameter; zoœcium with a rib: North Atlantic, south to Long Island Sound; common; Europe.

Suborder 2. CHILOSTOMATA.*

Colonies either erect or recumbent; zooids tubular, oval, or rectangular, and calcareous, horn-like, or membranous, the opening usually not terminal and usually closed by a movable operculum (Fig. 406); avicularia, vibracula, and oœcia usually present: about 36 families, all being marine, including the majority of *Bryozoa*.

Key to the families of *Chilostomata* here described:

a_1 Colony not incrusting or foliaceous but usually dendritic.
  b_1 Colony composed of a creeping base and erect shoots; no avicularia or vibracula.
    c_1 Zooids rising separately from the base.....1. Æteidae
    c_2 Erect shoots composed of many zooids each.....2. Eucrateidae
  b_2 Colony dendritic, without a creeping base.
    c_1 Avicularia sessile and fixed.
      d_1 Colony slender.
        e_1 Branches flattened.....3. Cellulariidae
        e_2 Branches cylindrical.....5. Cellariidae
      d_2 Colony foliaceous.....6. Flustridae
    c_2 Avicularia pedunculate and jointed.....4. Bicellariidae

* See "Non-incrusting Chilostomatous Bryozoa of the West Coast," by Alice Robertson, Univ. of Cal. Pub., Vol. 2, p. 235, 1905. "The Incrusting," etc., by same, ditto, Vol. 4, p. 253, 1908. "The Chilostomatous Bryozoa," by G. M. R. Levinson, 1909.

a_2 Colony incrusting or foliaceous and strongly calcified.
b_1 Colony incrusting; front wall more or less membranous.
c_1 No ridges on front wall.....7. MEMBRANIPORIDAE
c_2 Front wall with prominent transverse or radiating ridges.
8. CRIBRILINIDAE
b_2 Front wall not membranous; colony either incrusting or erect.
c_1 With a pore beneath the orifice.....9. MICROPORELLIDAE
c_2 With no such pore.
d_1 Zoœcia not perpendicular to general plane of colony and usually incrusting.
e_1 Opening of zoœcium with an indentation in lower lip..10. MYRIOZOIDAE
e_2 No such indentation.....11. ESCHARIDAE
d_2 Zoœcia vertical and heaped irregularly together.....12. CELLEPORIDAE

FAMILY 1. ÆTEIDAE.

Zoœcia tubular and erect, rising separately from a creeping stolonic stem with a terminal opening and a lateral membranous area at the upper end; operculum subterminal; no avicularia or vibracula: 1 genus.

Fig. 409
Ætea anguina (Osborn).

ÆTEA Lamouroux. With the characters of the family: 9 species.

A. anguina (L.) (Fig. 409). Zoœcia about 1 mm. high, white and glossy, more or less bent, with a spatulate upper end and a ringed stalk; stolon with regularly occurring thickenings, each of which is part of a zoœcium: Long Island Sound northwards from shallow to deep water on hydroids and seaweed; often common; Pacific coast; cosmopolitan.

FAMILY 2. EUCRATEIDAE.

Colony erect and branching; the zoœcia narrowest at the base and expanding upwards, being linked together in a single row, or in double rows placed back to back; openings usually oblique; no avicularia, vibracula, or opercula: 5 genera.

Fig. 410
Eucratea chelata (Osburn).

1. EUCRATEA Lamouroux. Colony composed of a creeping stolon and erect branching shoots; zoœcia in a single row placed end to end; opening large and oval; oœcia terminal; tentacular sheath terminating above in a ring of setae: about 4 species.

L. chelata (L.) (Fig. 410). Colony often much branched, occasionally not erect; branches spring from just below the opening: Vineyard Sound northwards, on seaweed, stones, etc., in shallow water and between tide lines; often common; Pacific coast; cosmopolitan.

2. Gemellaria Savigny. Colony erect, branching; zoœcia joined back to back, the pairs rising from the top of one another; aperture large: several species.

G. loricata (L.). Colony bushy, up to 20 cm. high, brown in color, composed of long, straight branches; zoœcia narrowed below; aperture oval: in northern seas; Vineyard Sound northwards; Alaska; Europe.

Family 3. CELLULARIIDAE.

Colonies erect, dichotomously branched; zoœcia in 2 or more rows in the same plane; avicularia and vibracula (Fig. 411), or the former alone, almost always present; opening not terminal, usually armed with spines and usually with an operculum: 8 genera.

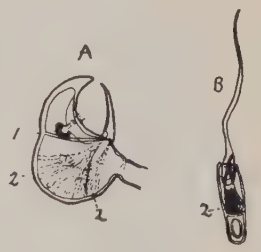

Fig. 411
A, an avicularium
B, a vibraculum
(Delage et Hérouard).
1, nerve; 2, muscles.

1. Menipea Lamouroux. Colony jointed, zoœcia oblong, widest above, attenuated downward, usually with sessile avicularia and oœcia; no vibracula: about 20 species, 7 American, mostly on the Pacific coast.

M. ternata (Ellis and Solander). Colony in small tufts, 25 mm. high; zoœcia in 2 rows, alternate and arranged in groups of 3; long fibers extend from the zoœcia: circumpolar; Cape Cod northwards from shallow to deep water, on hydroids and shells; Europe; Pacific coast.

Fig. 412
Caberea ellisi
(Osburn).

2. Caberea Lamouroux. Colony not jointed; zoœcia in 2 or more rows, quadrangular or ovate, with a very large opening; sessile avicularia and enormous vibracula as well as long, clasping fibers present: about 15 species, 1 American.

C. ellisi (Fleming) (Fig. 412). Colony with numerous branches, 25 mm. high; zoœcia in 2 to 4 rows and quadrangular; vibracula very long and serrate: circumpolar; Vineyard Sound northwards, from shallow to deep water; often common; Europe; Alaska.

Family 4. BICELLARIIDAE.

Colony erect and branching; zoœcia obliquely placed in 2 or more rows and conical or rectangular; stalked avicularia usually present and no vibracula; oœcia at the upper end of the zoœcia: 16 genera.

1. Bicellaria Blainville. Zoœcia cornucopia-shaped, loosely joined together and directed obliquely sideways: about 15 species.

B. ciliata (L.) (Fig. 413). Colony forming feathery tufts 12 mm. high, white in color; zoœcium with 4 to 7 very long slender spines along its upper margin: Atlantic coast, on hydroids and algae; Europe.

Fig. 413 *Bicellaria ciliata* (Osburn).

2. **Bugula** Oken. Zoœcia more or less quadrangular, arranged in 2 or more rows; opening large, not oblique; avicularia in form of a bird's head: about 35 species, 9 on the Atlantic coast, 8 on the Pacific.

Key to the species of *Bugula* here described:

a_1 Zoœcia in 2 rows.....B. TURRITA
a_2 Zoœcia in 3 or more rows.
b_1 Avicularia not at base of aperture.....B. FLABELLATA
b_2 Avicularia at base of aperture.....B. MURRAYANA

B. turrita (Desor). Colony up to 30 cm. or more in height, composed of flat branches growing in spirals, each branch with 2 rows of zoœcia, each zoœcium with a spine on the outer upper angle; color yellow: North Carolina to Casco Bay, very common in shallow water.

B. flabellata (Thompson) (Fig. 414). Colony up to 25 mm. high, composed of broad flat branches, each with from 3 to 7 rows of zoœcia, each upper angle with 2 spines; of an ashy color when dried, flesh color when alive: Vineyard Sound and northwards in shallow water; common; Pacific coast; cosmopolitan.

Fig. 414 *Bugula flabellata* (Osburn). 1, oœcium 2, avicularium

B. murrayana (Johnston). Colony a bushy tuft up to 50 mm. high and like the above, with 3 to 12 rows of zoœcia; each upper angle with a stout erect spine and 1 to 5 long slender spines on each lateral margin; long clasping fibers present; oœcia with radiating striae; straw color when dry: circumpolar, south to Vineyard Sound in rather deep water; Europe; Pacific coast.

Family 5. CELLARIIDAE.

Colony erect, slender, cylindrical, calcareous, usually dichotomously branching and jointed; zoœcia in 1 or more rows, lozenge-shaped or hexagonal and arranged in series around a central axis, making the branch cylindrical: 8 genera.

Cellaria Lamouroux. Colony jointed, the internodes connected by flexible horny tubes; zoœcia surrounded by a raised border; avicularia of simple type, resembling the ordinary zoœcium; oœcia concealed, the opening being just above the mouth: several species.

C. fistulosa (L.) (Fig. 415). Shape of zoœcium variable; orifice arched above, slightly incurved below; area surrounding it minutely pitted; avicularium just above it and in the same line with the zoœcium;

opening of oœcium round or oval: a northern species; on rocks, shells, etc., from shallow to deep water.

Family 6. FLUSTRIDAE.

Colony horn-like and flexible, erect, expanded, and foliaceous, usually consisting of broad branches attached by a narrow base; zoœcia contiguous and multiserial: 6 genera.

Flustra L. Colony frond-like; zoœcia in 1 or 2 layers, more or less quadrangular in form, rounded above, with a raised margin; avicularia

Fig. 415

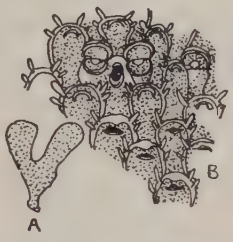

Fig. 416

Fig. 417

Fig. 415—*Cellaria fistulosa* (Cambridge Natural History). Fig. 416—*Flustra foliacea* (Cambridge Natural History). A, entire colony; B, several zooids.
Fig. 417—*Membranipora pilosa* (Osburn).

resembling the zoœcium and usually in line with them; oœcia concealed: several species.

F. foliacea (L.) (Fig. 416). Colony brownish in color, with a distinct odor of violets when fresh, up to 15 cm. high; zoœcia in rows and in 2 layers with 2 spines on a side; oœcia very shallow, the opening forming an arch over the upper end of the zoœcium: a northern species occurring on stones, shells, etc., in shallow water.

Family 7. MEMBRANIPORIDAE.

Colony calcareous or partly membranous and flattened, being incrusted on stones, shells, or seaweed, occasionally erect; zoœcia often more or less rectangular and with raised margins: several genera, with 150 species.

Membranipora Blainville. Zoœcia with raised margins and a depressed front wall which is wholly or partly membranous, and placed beside one another horizontally, forming a more or less irregular crust: 12 species near Woods Hole.

M. pilosa (L.) (Fig. 417). Zoœcia ovate, narrowed below, thickly punctured with minute oval pores and often with a silvery sheen; margin thickened, with 4 to 12 spines and just below it a corneous spine, sometimes short and sometimes very long; no oœcia: on stones, etc., from tide

lines to deep water, from Long Island Sound to the Arctic Ocean; very common; cosmopolitan.

M. monostachys Busk. Colony irregular, often radiate; zoœcia oval and elongate, with usually 6 to 10 pairs of marginal spines, of which the upper pair is directed upwards and the others bend inwards, often meeting in the middle; a single large basal spine is directed forwards and may be the only spine present; avicularia wanting; oœcia wanting: on stones, shells, seaweed, etc., from shallow to deep water; New Jersey to the Arctic Ocean; cosmopolitan.

M. craticula Alder. Zoœcia small, in regular radiating linear rows, oval; margin with about 14 flattish spines, of which the upper 2 are erect; the others extend across the cell, meeting in the middle of it; an avicularium often at the margin of the cell: on shells, etc., the colony forming small flabellate or roundish patches with a spongy appearance; from shallow to deep water; Arctic Ocean to Long Island Sound.

Family 8. CRIBRILINIDAE.

Colony incrusting or erect; zoœcia with the front wall more or less fissured or traversed by radiating furrows: 6 genera.

Cribrilina Gray. Colony incrusting; zoœcia contiguous; opening semicircular: about 20 species.

C. punctata (Hassall). Zoœcia oval, covered with small punctures, often arranged in rows; 4 or 5 marginal spines with usually an avicularium on each side of the orifice; oœcia rounded: Vineyard Sound and northwards; in shallow water; common on shells and pebbles; Europe.

C. annulata (Fabricius) (Fig. 418). Zoœcia ovate, convex, very distinct, with a median keel and about 6 transverse rows of punctured furrows; sometimes with 3 or 4 marginal spines; colony forming small reddish crusts: on stones and kelp, from shallow to deep water; often common north of Cape Cod; Europe.

Family 9. MICROPORELLIDAE.

Colony either incrusting or erect and foliaceous or dendritic; orifice more or less circular and with a straight lower margin and a semilunate or circular median pore immediately below it: 3 genera.

Microporella Hincks. Colony incrusting; orifice semicircular: several species.

M. ciliata (Pallas) (Fig. 419). Colony forming a delicate, irregular crust with a frosty sheen on seaweed, shells, etc.; zoœcia obscurely hexagonal and punctate; orifice bearing 3 to 7 long spines, which may be wanting; median pore lunate; large avicularium on one side with an acute

mandible often prolonged into a long, slender spine; oœcia globose, above the zoœcium: cosmopolitan; from tide lines to 300 fathoms.

Family 10. MYRIOZOIDAE.

Colony incrusting or rising in a foliaceous or dendroid expansion; zoœcia calcareous without raised margins or membranous area; opening with an indentation in the lower lip: 5 genera.

Schizoporella Hincks. Colony incrusting, sometimes several layers thick, or occasionally forming foliaceous expansions; avicularia usually lateral: over 100 species.

S. unicornis (Johnston) (Fig. 420). Zoœcia ovate or rectangular with a punctate surface, often silvery in appearance, an avicularium on one or both sides of the opening; orifice circular; oœcia globose, with

Fig. 418

Fig. 419

Fig. 420

Fig. 418—*Cribrilina annulata* (Osburn). Fig. 419—*Microporella ciliata* (Osburn). Fig. 420—*Schizoporella unicornis* (Osburn).

radiating grooves; colony forms a white or reddish spreading crust: South Carolina to Massachusetts Bay; from tide lines to deep water, on shells, stones, etc.; often very common; Europe.

S. hyalina (L.). Zoœcia elliptical, arranged irregularly in radiating rows; surface smooth and shiny, often glassy and transparent; opening terminal variable in shape, sometimes without the indentation; oœcia globose and punctate: Long Island Sound to the Arctic Ocean from tide lines to deep water; on stones, etc., and often forming nodules on hydroids; cosmopolitan; California.

Family 11. ESCHARIDAE.

Colony calcareous and incrusting, or erect, being lamellate or dendritic; zoœcia without raised margins or membranous area; sometimes with secondary opening, either elevated and enclosing an avicularium or not: numerous genera.

1. **Lepralia** Johnston. Zoœcia usually ovate, with a more or less horseshoe-shaped orifice which is arched above and straight and often narrow below; colony incrusting or foliaceous, often radiating from a central point: about 70 species.

L. pallasiana (Moll) (Fig. 421). Zoœcia large and coarsely punctate; orifice large, contracted on each side below the middle, often with an avicularium below the lower border; peristome raised and prominent; no oœcia; colonies forming large, reddish crusts: common; New Jersey to the Arctic Ocean, between tide lines and in shallow water.

Fig. 421 *Lepralia pallasiana* (Osburn).

L. pertusa (Esper). Zoœcia large, swollen, punctate; orifice round, contracted below by 2 lateral denticles, with usually a tubercle below it; oœcia globose: Gulf of St. Lawrence to Florida, on shells, etc., from shallow to deep water; colored patches radiating from a common center; Europe.

2. **Porella** Gray. Zoœcia ovate or elongate, with a semicircular orifice, above which is a secondary orifice, this being elongate or more or less triangular and enclosing an avicularium; colony incrusting or erect and foliaceous.

P. concinna (Busk). Zoœcia granular, arranged in lines; orifice arched above, with 2 spines, frequently with a raised margin; avicularium on lower lip; oœcia globose, prominent, often with a puncture in front: Cape Cod to Gulf of St. Lawrence, colony forming large circular reddish patches; Europe; California.

3. **Smittina** Norman. Zoœcia more or less quadrangular, with a small circular orifice which is surrounded by an elevated ridge or peristome; primary orifice dentate, secondary orifice with a sinus in front; colony incrusting or erect and foliaceous: numerous species.

Fig. 422 *Smittina trispinosa* (Osburn).

S. trispinosa (Johnston) (Fig. 422). Zoœcia ovate, very variable; orifice variable, usually round or pear-shaped, often being narrowed below, with 2 to 4 spines on young individuals, frequently with a large avicularium at one side, occasionally with 1 or 2 small oval avicularia; oœcia large, globose, usually with 2 or 3 punctures: Atlantic coast, colonies forming large yellow or whitish crusts; Europe; Pacific coast.

Fig. 423 *Mucronella peachi* (Osburn).

4. **Mucronella** Hincks. Zoœcia with a semicircular or reniform opening, the margin being elevated in front and with a prominent tooth below: colony incrusting; about 50 species.

M. peachi (Johnston) (Fig. 423). Zoœcia rhomboidal; opening large, with 6 slender marginal spines which may be wanting in old individuals; oœcia small: Long Island Sound to the Arctic Ocean, from tide lines to deep water, colony forming a large whitish irregular patch of solid texture; Europe.

Family 12. CELLEPORIDAE.

Zoœcia calcareous, tubular, more or less erect, with a terminal opening, and irregularly heaped together; colony usually incrusting, often composed of many layers of cells; sometimes erect: 2 genera.

Cellepora Fabricius. With the characters of the family: numerous species.

C. americana Osburn. Colony incrusting or rising in nodular branches a few millimeters high, growing on hydroid and bryozoan stems and algae; zoœcia ovate, more or less erect, heaped upon one another and turned in various directions; orifice circular with a notch and a rostrum which overhangs it and an avicularium at its base: Long Island to Arctic Ocean; often common.

C. pumicosa (L.). Colony massive, scabrous, composed of many layers of pinkish color when fresh; zoœcia subcylindrical or ovate, smooth, erect, crowded; orifice round, with a thin, raised margin, immediately below which a tall rostrum bearing an avicularium is often present: Atlantic and Pacific coasts, covering stones and shells in shallow water; common.

Suborder 3. CTENOSTOMATA.

Opening terminal and closed by an operculum of setae set in a thin membrane; zoœcium never calcareous but fleshy or membranous; no avicularia, vibracula, or oœcia: 11 families, 10 of which are marine.

Key to the families of *Ctenostomata* here described:

a_1 Animals marine.
  b_1 Colony fleshy, forming irregular, incrusting or erect masses.
    c_1 Opening of zoœcium not bilabiate.....1. Alcyonidiidae
    c_2 Opening with 2 distinct lips.....2. Flustrellidae
  b_2 Colony branching, either recumbent or erect.
    c_1 All the tentacles erect, forming a circle.....3. Vesiculariidae
    c_2 Tentacles not in a circle, 2 being turned back.....4. Valkeriidae
a_2 Animals in fresh water.....5. Paludicellidae

Family 1. ALCYONIDIIDAE.

Colony fleshy or membranous, forming either an expanded and gelatinous crust on seaweed or rocks, or being erect and cylindrical or compressed; zoœcia closely joined and developing by budding from one another and not from a stolon; opening closed by an invagination of the tentacular sheath: 1 genus.

Alcyonidium Lamouroux. With the characters of the family: 18 species.

A. mytili Dalyell. Colony an extensive gelatinous crust, cylindrical or somewhat flattened, and irregular in shape and reddish, gray, or yel-

lowish in color; zoœcia hexagonal, closely packed together: from the Arctic Ocean south to Long Island Sound, on stones, piles, crabs, etc., from tide lines to deep water; Europe.

A. hirsutum (Fleming) (Fig. 424). Colony incrusting or erect, compressed, expanded, and branched, yellowish-brown or reddish in color, the surface covered with conical papilla, between which are the orifices: Long Island Sound to Arctic Ocean in shallow water, incrusting the stems of fucus and other plants; common; Europe.

Family 2. FLUSTRELLIDAE.

Colony similar to the above, but the opening is bilabiate, with a movable lip which acts as an operculum; larva (*Cyphonautes*) with a bivalve shell: 1 genus.

Flustrella Gray. With the characters of the family: 3 species.

F. hispida (Fabricius) (Fig. 425). Colony a thick, brown crust, roughened by numerous reddish spines; zoœcium ovate or hexagonal, with

Fig. 424

Fig. 425

Fig. 426

Fig. 424—*Alcyonidium hirsutum* (Osburn). Fig. 425—*Flustrella hispida* (Osburn). Fig. 426—*Bowerbankia gracilis* (Osburn).

a raised opening around which are one or more tall, red spines, which may also be present along the margin of the cells: circumpolar, south to Long Island Sound and Alaska, incrusting the stems of fucus, etc.; common; Europe.

Family 3. VESICULARIIDAE.

Colony horn-like or membranous, branching, and either erect or recumbent, the zoœcia contracted below, budding off from a distinct stem: 5 genera.

1. **Bowerbankia** Farre. Colony recumbent; zoœcia cylindrical, in clusters often spirally arranged; 8 to 10 tentacles in a circle; gizzard present between stomach and œsophagus: 20 species.

B. gracilis Leidy (Fig. 426). Colony creeping, the cylindrical zooids rising separately from the recumbent stem: coast of New England, on hydroids, seaweed, etc.

2. **Amathia** Lamouroux. Colony erect; zooids in a double series: several species.

A. dichotoma (Verrill) (Fig. 427). Colony 5 cm. or more high and white in color, repeatedly forking, a short, dark-brown segment being at the base of each fork; zooids crowded together spirally in groups of 6 to 12 each: New Jersey northwards, on algae, rocks, etc., in shallow water; often common.

Family 4. VALKERIIDAE.

Colony branching and erect or recumbent and creeping; tentacles 8 in number, 2 of which are bent outwards towards the side and 6 are erect; zoœcia contracted below: 1 genus.

Valkeria Fleming. With the characters of the family: 4 species.

Fig. 427

Fig. 428

Fig. 429

Fig. 427—*Amathia dichotoma* (Osburn). Fig. 428—*Valkeria uva* (Osburn)
Fig. 429—*Paludicella ehrenbergi.*

V. uva (L.) (Fig. 428). Colony composed of delicate jointed tubes, which creep over seaweed, hydroids, or shells, or may stand erect to a height of 5 to 10 cm. giving off paired branches; zooids in thick clusters, which are principally at the base of the branches and on them: from New Jersey northwards, in shallow water; Europe.

Family 5. PALUDICELLIDAE.*

Colony with a horn-like or membranous cuticula and composed of delicate, jointed, branching, recumbent or partly erect tubes, which creep over stones and sticks in slow streams and fresh-water ponds: 2 genera.

Key to the genera of *Paludicellidae:*

a_1 Zooids recumbent, not rising from stolons.....1. Paludicella
a_2 Zooids erect, rising from stolons.....2. Pottsiella

1. Paludicella Gervais. Colony consists of series of club-shaped zooids placed end to end and separated from one another by partitions; opening lateral; branches usually paired; no statoblasts present but hibernacula or winter buds which persist when the rest of the colony has died: 1 species.

P. ehrenbergi van Beneden (Fig. 429). Colony recumbent or partly erect; length of zooid 2 mm.; number of tentacles about 16: cosmopolitan.

* See "Observations on Budding in Paludicella and Some Other Bryozoa," by C. B. Davenport, Bull. Mus. Comp. Zool., Vol. 22, 1890.

2. **Pottsiella** Kraepelin. Colony consists of stolons from which at intervals single erect, cylindrical zooids arise; opening terminal: 1 species.

P. erecta* (Potts). Length of zooid 1.5 mm.; number of tentacles about 20: Montgomery County, Pennsylvania.

Order 2. PHYLACTOLÆMATA.†

Lophophore oval or horseshoe-shaped; epistome present, projecting over the mouth; statoblasts present, which usually have a broad marginal band of air cells called the float which sustains them in the water: in fresh water; 3 families and about 30 species, 7 American.

Key to the families of *Phylactolæmata:*

a_1 Colony branched, provided with an opaque chitinous or hyaline cuticula; statoblasts without hooks.
b_1 Lophophore nearly circular; statoblasts without float..1. Fredericellidae
b_2 Lophophore horseshoe-shaped; statoblasts with float....2. Plumatellidae
a_2 Colony massive, secreting a gelatinous base; statoblasts with float and hooks.....3. Cristatellidae

Family 1. FREDERICELLIDAE.

Colony tubular, branched in form of antlers; lophophore oval; cuticula opaque and brown, rarely gelatinous and hyaline; tentacles not over 24; statoblasts dark brown, elliptical, without float: 1 genus.

Fig. 430
Fredericella sultana.
A, colony (Davenport).
B, statoblast
(Süssw. F. Deut.).

1. Fredericella Gervais. Colony dendritic and either recumbent or erect, attached either entirely or partially to the under surface of stones or sticks in ponds and streams, usually in dark places; lophophore oval, bearing usually 20 to 22 tentacles: 1 American species.

F. sultana (Blumenbach) (*F. walcottii* Hyatt; *F. pulcherrima* Hyatt; *F. regina* Leidy) (Fig. 430). Form of colony differs in different localities, consisting of intertwining branches which adhere to the substratum or form a dense clump: cosmopolitan.

Family 2. PLUMATELLIDAE.

Colony consists either of cylindrical tubes which are either branched or form massive clumps or of hyaline, recumbent, lobed tubes, or of hyaline erect, slightly lobed sacs; tentacles 40 to 60 on a horseshoe-shaped

* See "On Paludicella erecta," by E. Potts, Proc. Acad. Nat. Sci., 1884, p. 213.
† See "Observations on Polyzoa, Suborder Phylactolæmata," by A. Hyatt, Proc. Essex Inst., Vols. 4 and 5, 1866-1868.

lophophore; statoblasts elliptical, without marginal hooks but with a float: several genera.

Key to the genera of *Plumatellidae* here described:

a_1 Statoblasts oval; zooids uniformly spaced.....1. PLUMATELLA
a_2 Statoblasts lenticular; zooids grouped at intervals.....2. LOPHOPUS

1. PLUMATELLA Lamarck. Colony consists of cylindrical, more or less branched tubes, either recumbent or erect, which lie extended on the substratum or form a clump; 40 to 60 tentacles: about 20 species, 3 American; in ponds and streams, usually not in the light; the commonest fresh-water bryozoans.

P. princeps Kraepelin (*P. diffusa* Leidy) (Fig. 431). Colony creeping or erect, often much branched, the branches sometimes fused together; cuticula brown, with a keel that broadens at the aperture; statoblast elongated: cosmopolitan.

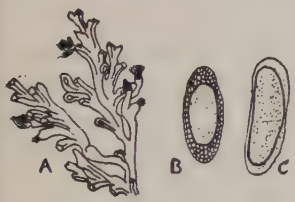

Fig. 431

Fig. 432

Fig. 431—*Plumatella princeps*. A, a colony (Davenport); B, a floating statoblast; C, a stationary statoblast (Süssw. F. Deut.). Fig. 432—*Plumatella polymorpha*. A, a colony (Davenport); B, a floating statoblast; C, a stationary statoblast (Süssw. F. Deut.).

P. polymorpha Kraep. (*P. nitida* Leidy; *P. arethusa* Hyatt) (Fig. 432). Colony creeping or erect, often richly branched; cuticula usually transparent, rarely brown or keeled; statoblast nearly circular, sometimes with angular margin: cosmopolitan.

P. punctata Hancock (*P. vesicularis* Leidy; *P. vitrea* Hyatt) (Fig. 433). Colony creeping, often thickly branched; cuticula colorless, transparent, the elevated mouth cone being wrinkled and spotted with white; statoblast nearly circular: in America and Europe.

Fig. 433

Fig. 434

Fig. 433 — Statoblast of *Plumatella punctata* (Süssw. F. Deut.). Fig. 434—Statoblast of *Lophopus crystallinus* (Süssw. F. Deut.).

2. LOPHOPUS Dumortier. Colony thick, erect, and sometimes lobed; cuticula gelatinous; about 60 tentacles; statoblast with acute ends; 1 American species.

L. cristallinus (Pallas) (Fig. 434). Colony up to 10 mm. long: in ponds and slowly-flowing streams, chiefly on water plants; rare; America and Europe.

Family 3. CRISTATELLIDAE.

Colonies forming compact hyaline groups which secrete a gelatinous base; aperture slightly elevated above the level of the group; statoblasts large, about 1 mm. in diameter, provided with hooks: 2 genera.

Key to the genera of *Cristatellidae:*

a_1 Statoblast with a row of marginal hooks; gelatinous base often very thick.....1. Pectinatella

a_2 Statoblast with 2 rows of marginal hooks; gelatinous base forms a thin sole.....2. Cristatella

1. **Pectinatella** Leidy. Many associated colonies in rosette-shaped groups on a gelatinous base which may attain a thickness in the autumn of 40 cm.; the youthful colony is locomotory: 1 American species.

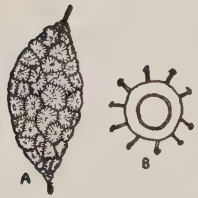

Fig. 435—*Pectinatella magnifica* (Davenport). A, a thick gelatinous mass surrounding a stick on which are numerous colonies; B, statoblast.

P. magnifica Leidy (Fig. 435). Tentacles 60 to 84 in number; statoblasts circular, black in color, with 10 to 22 marginal anchor-shaped hooks: often common on stones, sticks, etc., in ponds and streams; North America; introduced locally into Europe and Japan.

2. **Cristatella** Cuvier. Colony an elongate, gelatinous mass with a thin, flat sole on which it creeps; the zooids are located on the upper surface of the colony and may contract into a common cavity; statoblasts circular with 2 rows of marginal hooks: 1 species.

Fig. 436 Statoblast of *Cristatella mucedo* (Süssw. F. Deut.).

C. mucedo Cuv. (*C. idae* Leidy; *C. ophidioidea* Hyatt; *C. lacustris* Potts) (Fig. 436). Young colony circular, later elongate, attaining in the autumn a length of 28 cm.; usual length 3 to 5 cm.; 80 to 90 tentacles; statoblasts with 10 to 34 hooks in one row and 20 to 50 in the other: America and Europe, in ponds and sluggish streams on submerged sticks, pond lily leaves, etc.; not common.

Subphylum 5. BRACHIOPODA.*

Sessile, marine, mollusk-like animals in which the body is enclosed in a bivalve, calcareous, or horny shell, one valve of which is dorsal and one valve ventral. The shells (Fig. 437) can be opened and closed by means of muscles, the hinge end being posterior and the opening anterior

* See "Catalogue of the Recent Species of the Class Brachiopoda," by W. H. Dall, Proc. Acad. Nat. Sci., Phil., 1873, p. 177. "A Monograph of Recent Brachiopoda," by T. Davidson, Trans. Lin. Soc., 2nd ser., Vol. 4, 1886-1888. "Revision of the Families of Loop-bearing Brachiopoda," by C. E. Beecher, Trans. Conn. Acad., Vol. 9, 1893.

in position. The animal is attached to some more or less fixed object by means of the peduncle, a stout, muscular stalk which is a prolongation of the hinder end of the body and passes either between the valves of the shell or through a hole in the projecting ventral valve; in a few species (*Crania*) the whole ventral valve is attached, no peduncle being present.

The soft parts of the body, which lie between the hinder and middle portions of these shells, are very short and broad, and from them two leaf-like folds called the dorsal and the ventral mantles extend forwards and cover the inner surface of the forward portion of the shells. Two additional projections of the anterior body wall also extend forwards and occupy the space between the two mantles. These are the tentacular arms or lophophores, a pair of ridges or of bent or coiled arms which in the

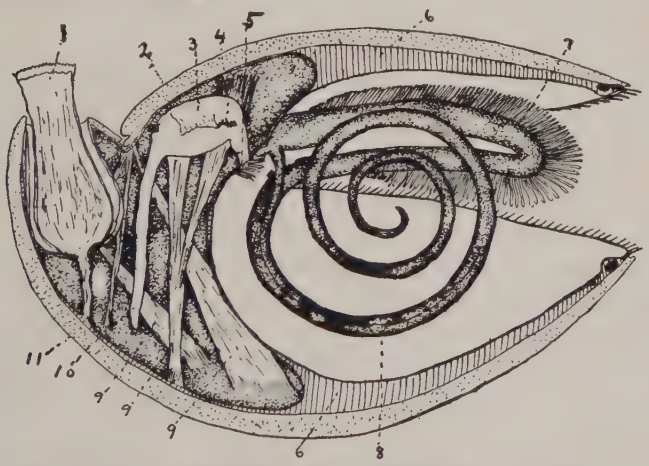

Fig. 437—Diagram of a brachiopod (Delage et Hérouard). 1, peduncle; 2, dorsal shell; 3, stomach; 4, liver ducts; 5, mouth; 6, mantle; 7, gills; 8, lophophore; 9, muscles; 10, intestine; 11, ventral shell.

Testicardines are supported by a calcareous skeleton proceeding from the dorsal valve of the shell. These arms are the largest and most conspicuous organs in the body and have given the group its name: they are respiratory and sensory in function, and are also of use in the ingestion of food. Both they and the mantles contain a cavity which is in direct communication with the body cavity. Running along the surface of each ridge or arm is a ciliated groove along one side of which is a row of ciliated tentacles. By the action of these cilia the minute organisms which form the food of the animal are swept into the mouth.

The mouth lies between the base of the arms and is without special jaws or lips; it opens into a digestive tube in which an œsophagus, stomach, and intestine may be distinguished. Sac-like digestive glands (livers) open into the stomach. The *Testicardines* have no anus: in the *Ecardines*

the anus is at the hinder end of the body between the edges of the shells. The nervous system consists of a pair of ganglia dorsal to the œsophagus, a ventral pair, connecting commissures and radiating nerves. There are no special sense organs in the adult animal, although the larva may have eye spots and otocysts. The circulatory system consists of a heart, a large vein which enters it anteriorly, and arteries which proceed to the spaces of the body cavity. The excretory organs consist of a pair (two pairs in *Rhynchonella*) of nephridial tubes which open into the body cavity at one end and into the mantle cavity at the other. The sexes are as a rule separate. The two pairs of genital glands lie near the intestine and discharge their products into the body cavity, whence they find their way to the outside through the nephridia. The larva is a trochophore, and is made up of three divisions, from the middle one of which the mantle folds develop: after a few hours of free life the larva attaches itself.

*Habits and Distribution.**—All *Brachiopoda* are attached to rocks, or other similar objects, except the *Lingulidae,* which live in vertical burrows in the sand. Most of the species live in shallow water in the neighborhood of continents: a few, however, are found in the deep sea. They are not generally distributed over the world but are localized, as is the case with many ancient groups of animals, but are often found in large numbers where they do occur. Brachiopods have flourished during all the geological ages from the Cambrian down to the present time, the genus *Lingula,* which is still plentiful in the Indian and Pacific Oceans, being the oldest known genus of animals. About 2,500 fossil species have been discovered, mostly in the Paleozoic rocks, only about 120 living species being known.

History.†—The conspicuous shells of the *Brachiopoda* attracted the attention of the older naturalists, by whom the animals were almost universally regarded as mollusks. The name *Brachiopoda* was given them in 1807 by Duméril. In 1873 and 1874 Morse and Kowalevsky independently demonstrated by a study of their embryology that the affinities of brachiopods were not with the *Mollusca* but rather with the *Annelida.* Brooks held them to be *Bryozoa,* while Huxley and Claus placed them among the *Molluscoidea,* a subkingdom or phylum originally created by Milne-Edwards to contain the *Bryozoa* and *Tunicata.* Conklin and others

* See "Observations on Living Brachiopoda," by E. S. Morse, Mem. Bost. Soc. Nat. Hist., Vol. 5, 1902.

† See "On the Embryology of Terebratulina," by E. S. Morse, Mem. Bost. Soc. Nat. Hist., Vol. 2, 1873. "On the Systematic Position of the Brachiopoda," by E. S. Morse, Proc. Bost. Soc. Nat. Hist., Vol. 15, 1873. "On the Development of the Brachiopoda," by A. Kowalevsky, Abst., by A. Agassiz, Am. Jour. Sci., 1874. "The Development of Lingula and the Systematic Position of the Brachiopoda," by W. K. Brooks, Sci. Results of Sess. of 1878, Chesapeake Zool. Lab. "The Embryology of a Brachiopod," etc., by E. G. Conklin, Proc. Am. Phil. Soc., Vol. 41, 1902.

quite recently have shown the relationship between the *Brachiopoda* and *Phoronis*. The affinities of the *Brachiopoda* are thus still obscure, but are undoubtedly with the *Bryozoa* and *Phoronis*.

The subphylum contains 2 orders.

Key to the orders of *Brachiopoda:*

a_1 Shell without a hinge joining the valves.....1. ECARDINES
a_2 The valves of the shell joined by a hinge.....2. TESTICARDINES

ORDER 1. ECARDINES.

Shell horn-like or calcareous, the valves not being joined posteriorly by a hinge but only by muscles; mantles also not joined; no calcareous arms projecting from the dorsal valve to support the tentacular arms; anus present: 3 families with about 32 living and 400 fossil species, most of the latter being Paleozoic.

Key to the families of *Ecardines* here described:

a_1 Peduncle present; animal living in sand.....1. LINGULIDAE
a_2 Peduncle not present; animal attached by ventral valve.....2. CRANIIDAE

FAMILY 1. LINGULIDAE.

Shell more or less rectangular in shape, horn-like in texture, with valves of equal size, truncated in front and pointed behind; peduncle contractile and usually long; tentacular arms spiral, with about 6 whorls; mantle very vascular, with long stiff setae on the edges: 16 species, in 2 genera, of which *Lingula* is found in the Pacific and Indian Oceans and *Glottidia* on both shores of America; 100 fossil species.

GLOTTIDIA Dall. Shell smooth and linguiform; dorsal valve with 2 internal, sharp, incurved laminae diverging from the beak and extending a third of the length of the shell; ventral valve, with a mesial septum extending forwards from the beak: about 4 species, on both Atlantic and Pacific coasts of America.

Fig. 438.—*Glottidia audebarti* (Tryon).

G. albida (Hinds). Shell narrow, oval, tapering at the beak, very slightly curved in front, smooth, and white; peduncle stout and short, 45 mm. long; shell 30 mm. long: Pacific coast from San Diego to Monterey, from low-water mark to 60 fathoms.

G. audebarti* (Broderip) (*Lingula pyramidata* Stimpson) (Fig. 438). Shell narrow, tapering at the back, front margin nearly straight; color white, with transverse bands of green; peduncle very long and slender; animal hermaphroditic; length of shell 27 mm., breadth 10 mm.; length

* See "A Study of the Structure of Lingula (Glottidia) pyramidata Stimp.," by H. E. Beyer, Stud. Biol. Lab., Johns Hopk., Vol. 3, 1886.

of peduncle 16 cm.: North Carolina to Florida; in vertical burrows in the sand between tide lines, the contractile peduncle extending straight down and the opening of the shell just reaching the water.

Family 2. CRANIIDAE.

Shell more or less quadrate or circular in shape and without a peduncle, being attached by the ventral valve to a rock; dorsal valve limpet-like; tentacular arms free and spiral; mantle extending to the edges of the valve, its margin being plain: 1 genus.

Crania Retzius. Shell smooth or radiately striated: 4 species.

C. anomala (O. F. Müller). Shell brownish in color, 18 mm. long and 22 mm. broad: Florida Keys and the West Indies, in 100 fathoms.

Order 2. TESTICARDINES.

Shell calcareous, the 2 valves being joined by a hinge; mantles also fused behind; ventral valve larger than the dorsal and with a beak at the hinder end through which the peduncle passes; tentacular arms supported by calcareous arms which proceed from the dorsal valve; anus wanting: 3 families and about 80 species; about 2,200 fossil species.

Key to the families of *Testicardines* here described:

a_1 Shell with a sharp, hook-like beak.....1. Rhynchonellidae
a_2 Beak not hook-like, but prominent.....2. Terebratulidae

Family 1. RHYNCHONELLIDAE.

Shell more or less triangular with a sharp, hook-like beak; calcareous arms long and slender, curving towards each other; tentacular arms long and spiral: 2 genera and 8 species.

Rhynchonella Fischer. Shell with radiating ridges; dorsal valve very convex, ventral valve more flattened: 6 species.

R. psittacea (Gmelin). Shell brown or black, 26 mm. long and not quite so wide: circumpolar, being found south to the Gulf of St. Lawrence and to the Aleutian Islands, in shallow water.

Family 2. TEREBRATULIDAE.

Shell round or oval, the lower valve with a prominent perforated beak and 2 curved hinge teeth, dorsal valve with a hinge process and a slender calcareous loop: about 10 genera and 68 species.

Key to the genera of *Terebratulidae* here described:

a_1 Calcareous loop short.....1. Terebratulina
a_2 Calcareous loop long.
b_1 Loop with its principal stem attached but once.....2. Waldeheimia
b_2 Principal stem attached twice.....3. Terebratella
b_3 Reflected part of loop attached at the tip.....4. Laqueus

1. **Terebratulina** D'Orbigny. Shell punctate, with 5 radiating striations; calcareous loop short and forming either a perfect or a broken ring: 8 species; 22 fossil species.

T. septentrionalis (Couthouy) (Fig. 439). Shell thin and semi-transparent, yellowish or whitish, broadly oval; beak projecting but little, truncated horizontally, with a large orifice; 13 mm. long and 8 mm. broad: coast of New England, in 20 fathoms off Cape Cod, at low-water line farther north; common.

T. caput-serpentis (L.). Shell oval, whitish or yellowish; 25 mm. long; 17 mm. wide: Europe; Florida and the West Indies (var. *cailleti*); Pacific coast from San Diego to Aleutian islands (var. *unginculata*).

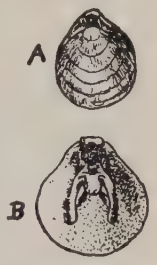

Fig. 439—*Terebratulina septentrionalis* (Tryon). A, dorsal aspect; B, inner surface of dorsal shell, showing calcareous arms.

2. **Waldheimia** King. Shell globose and smooth, calcareous loop composed of 2 slender branches which extend from the hinge almost to the front edge of the shell, then curve backwards to the center, where they join: 10 species; 90 fossil species.

Fig. 440—*Terebratella transversa* (Keep). A, natural position, with the dorsal shell uppermost; B, dorsal aspect.

W. floridana Pourtalès. Shell triangular, gray or brownish-white in color; length 22 mm.; width 25 mm.; depth 14 mm.: Florida reefs and the West Indies, in 100 to 200 fathoms; abundant.

3. **Terebratella** D'Orbigny. Shell ovoid or round; loop long and like *Waldheimia,* but with its principal stem twice attached: 9 species.

T. transversa (Sowerby) (Fig. 440). Shell variable in shape, usually wider than long; length 30 mm.; breadth 38 mm.; depth 20 mm.; color from light yellow to dark purple: Monterey, California, northwards, in 15 to 20 fathoms, the commonest brachiopod on the coast.

T. spitzbergensis Davidson. Shell whitish-yellow and longer than wide; valves equally convex, smooth, and strongly punctate; length 9 mm.; breadth 7 mm.; depth 3.5 mm.: circumpolar; south to Gulf of St. Lawrence, in 40 to 400 fathoms.

4. **Laqueus** Dall. Shell broadly ovoid; loop long like *Terebratella,* but with the reflected portion attached by a connecting branch on each side to the principal stem: 3 species.

Fig. 441
Laqueus californicus (Keep).

L. californicus (Koch) (Fig. 441). Shell 6 cm. long, 5 cm. broad, and 25 mm. deep; bright yellowish or reddish-brown in color: Santa Barbara County, California, and northwards, in 90 fathoms, being smaller towards the north.

Subphylum 6. PHORONIDEA.*

Sessile, marine worms living in chitinous tubes in shallow water, which have at the anterior end of the body a horseshoe-shaped tentacular crown or lophophore. The animals are gregareous, their tubes being often twisted together, but without, however, communicating with one another. The tubes are also covered with sand, pieces of shell, etc., which give them a characteristic appearance. The lophophore consists of a double ridge, each part of which bears a single row of tentacles, its lateral extremities forming a spiral coil on each side. The mouth and the anus are near together in the middle of the lophophore, but are separated by a long projection of the body wall called the epistome. Near the anus are the paired orifices of the kidneys. The body cavity is large and is divided by a diaphragm into two parts, an upper or anterior, which is continuous with the cavities of the epistome and the tentacles, and a lower, which contains the viscera: the diaphragm is pierced by blood vessels and the œsophagus. The digestive tract is U-shaped, consisting of the œsophagus, stomach, and intestine, and is supported by longitudinal mesenteries. Two circulatory fluids are present, a colorless fluid in the body cavity and a red fluid in a system of closed vessels which lie along the two limbs of the digestive tube and are distributed to the tentacles and other organs. The kidneys are a pair of tubes which communicate between the body cavity and the outside. The nervous system is subepithelial in position and consists of a nerve ring surrounding the mouth and nerves going from it to the tentacles. The animals are hermaphroditic, the gonads lying near the stomach and discharging their products into the cœlom, whence they find their way to the outside through the kidney pores. The development is a metamorphosis, the characteristic larva being known as the actinotrocha.

Fig. 442—*Phoronis architecta*—young individual with about 30 tentacles (Cowles). 1, epistome; 2, lophophore; 3, digestive tract.

The systematic position of the animals has long been a matter of dispute, but they are now usually placed near the *Bryozoa* and *Brachiopoda*. The subphylum contains a single genus and about a dozen species, of which two are American.

Phoronis Wright. With the characters of the subphylum: 11 species.

* See "Phoronis architecta," by R. P. Cowles, Mem. Nat. Acad., Vol. 10, p. 76, 1905. "On Phoronis pacifica sp. nov.," by H. B. Torrey, Biol. Bull., Vol. 2, p. 283, 1901.

P. architecta Andrews (Fig. 442). Tubes straight and about 13 cm. long and 1 mm. wide; anterior portion of body flesh color, posterior portion reddish or yellowish; tentacles about 100 in number; lophophore not spirally coiled at the ends: North Carolina, in sand flats near the low-water mark, the tubes being isolated and covered with sand grains; often common.

P. pacifica Torrey. Length of tube 9 cm.; diameter 2 mm.; each spiral of lophophore with 1½ to 2 turns; tentacles 170 to 200 in number; tube straight, cylindrical, incrusted with sand: Puget Sound; Humboldt Bay, California; in sand and mud flats.

Subphylum 7. CHÆTOGNATHA.*

Elongate, transparent worms of small size which live exclusively in the sea, preying on other small organisms. The body is long and slender and unciliated, and is provided with two or three pairs of horizontal fins. Surrounding the mouth at the front end of the body are long, paired, prehensile bristles or hooks and one or two rows of small teeth (Fig. 443, B). A large body cavity is present, which is lined with a peritoneum and is divided by transverse septa into three compartments. The anus is at the hinder end of the body and between it and the mouth lies the straight digestive tract: longitudinal mesenteries join the intestine with the dorsal and ventral body walls. The nervous system is subepithelial; a large cerebral ganglion forms the brain and is connected with a large ventral trunk ganglion in the middle of the body by commissures. The brain sends off nerves to the two eyes and the unpaired olfactory organ behind them. No special respiratory, excretory, or circulatory organs are present. The animals are hermaphroditic, the sex cells arising from the peritoneum. The two ovaries are in the middle division of the body, the oviducts opening near them: the testes are in the hinder division of the body; the spermatozoa escape to the outside through a pair of prominent seminal vesicles just in front of the tail fins. In the development the mesoderm is formed by the growth of paired pouches from the archenteric walls, the fused cavities of the pouches becoming the cœlom, a process characteristic of many annelids and also of the *Chordata*.

The *Chætognatha* are found in all seas, from the surface to the greatest depths, being often present in immense numbers. Six genera and about 30 species are known.

* See "The Known Chætognatha of American Waters," by F. S. Conant, Johns Hopk. Univ. Cir., Vol. 15, p. 82, 1896. "Chætognathi," by R. von Ritter-Zahony, Das Tierreich, 1911. "Classification, etc., of the Chætognatha," etc., by E. A. Michael, Univ. of Cal. Pub., Vol. 8, p. 21, 1911.

Key to the American genera of *Chætognatha:*

a_1 Two pairs of fins besides the caudal fin.....1. SAGITTA
a_2 One pair of fins besides the caudal fin.
b_1 Fins near the middle; body slender, with 1 row of teeth....2. EUKROHNIA
b_2 Fins near the tail; body broad, with 2 rows of teeth.....3. PTEROSAGITTA

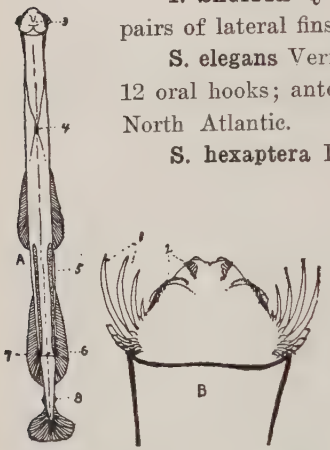

Fig. 443—*Sagitta elegans* (Zahony). A, entire animal; B, head. 1, prehensile hooks; 2, teeth; 3, mouth; 4, ventral ganglion; 5, female genital organs; 6, anus; 7, female genital pore; 8, male genital pore.

1. SAGITTA Quoy and Gaimard. Slender worms with 2 pairs of lateral fins: about 25 species.

S. elegans Verrill (Fig. 443). Length up to 3 mm.; 9 to 12 oral hooks; anterior teeth 4 to 8; posterior teeth 6 to 9: North Atlantic.

S. hexaptera D'Orbigny. Length 6 mm.; oral hooks 5 to 10; anterior teeth 3 to 4; posterior teeth 3 to 5: Martha's Vineyard; cosmopolitan.

2. EUKROHNIA Ritter-Zahony. A single lateral fin on each side near middle of body; body slender: 3 species.

E. hamata (Mobius). Length 4 mm.; oral hooks 8 to 10; 15 to 28 teeth in a single row; ovary reddish: cosmopolitan; Martha's Vineyard.

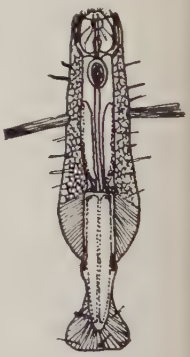

Fig. 444 *Pterosagitta draco* (Cambridge Natural History).

3. PTEROSAGITTA Costa. Body broad; a single pair of lateral fins near the tail; an expansion of the integument extending along the side of the body in front of each lateral fin to the head: 1 species.

P. draco (Krohn) (Fig. 444). Length 10 mm.; oral hooks 4 to 10; anterior teeth 6 to 9; posterior teeth 12 to 18; forward of the middle of the body on each side is a bundle of long setae: cosmopolitan.

SUBPHYLUM 8. SIPUNCULOIDEA.

Marine worms which, together with the *Echiurida,* are often included in a class of the *Annelida* called the *Gephyrea.* This is a name given them by Quatrefages (1847) to signify the belief that they bridge the gulf between the *Annelida* and the *Echinodermata,* the earlier zoologists having grouped them with the holothurians. The total lack of segmentation, however, at any period of the life of most of the *Sipunculoidea,* and the absence of metameric organs, have made it necessary to remove them from the *Annelida,* although the fact that they pass through the

trochophore stage indicates a close connection with the immediate ancestors of that group.

The *Sipunculoidea* are more or less elongated worms, the largest of which are 20 cm. or more in length, which live in the sand or mud, either free or in tubes or snail shells. The body is cylindrical and very contractile, unsegmented and not ciliated, and without metameric appendages, spines, or bristles; it is made up of two divisions, a usually slender anterior portion called the introvert, which can be invaginated, and the thicker hinder portion. The subphylum contains two classes.

Key to the classes of *Sipunculoidea:*

a_1 Body elongate; anus at base of introvert; tentacles usually present. 1. SIPUNCULIDA

a_2 Body robust; anus at hinder end; no tentacles.....2. PRIAPULIDA

CLASS 1. SIPUNCULIDA.*

Elongated worms with short, hollow tentacles at the forward end which are either distinct or more or less united and usually surround the mouth, and with the anus in the dorsal surface near the base of the introvert. The body wall consists of a cuticula, a single-layered hypodermis, and the muscles. The hypodermis gives rise to large glands which lie beneath it, in certain species enveloped in a gelatinous connective tissue called the cutis, and open through the cuticula to the outer surface. The muscles consist of an outer circular and an inner longitudinal layer and between them delicate oblique muscles, which, however, are not present in the introvert. The longitudinal muscles in certain species (*Sipunculus*) are split up into regularly recurring bundles, which produce a lattice-like effect (Fig. 446). The body cavity is voluminous and is bounded by a ciliated peritoneal lining; it contains a corpusculated blood fluid. Two or four retractor muscles extend back from the front end of the base of the introvert, by means of which invagination is effected. The digestive system consists of a narrow tube of about the same diameter throughout, which extends from the mouth at the front end to near the hinder end of the body, then turns on itself and extends forward to the anus. The two limbs of the intestine are usually twisted spirally together, in certain species around a single muscle strand called the spindle muscle. A blood vascular system is present in form of an œsophageal ring canal, tentacular canals which extend from the ring canal into the tentacles, and one or two contractile cæca (hearts) which extend from the ring canal a short distance along the œsophagus. These organs contain a fluid which serves to extend the tentacles, which are probably respiratory as well as sensory in

* See "Die Sipunculiden," by E. Selenka, in Reisen im Arch. d. Philipp, von C. Semper, 1883. "The Sipunculids of the Eastern Coast of North America," by J. H. Gerould, Proc. U. S. Nat. Mus., Vol. 44, p. 373, 1913.

function. A pair of nephridia, called the brown tubes, opens to the outside near the anus. The nervous system consists of a cerebral ganglion on the dorsal side of the œsophagus, which is connected by a pair of commissures with an unsegmented ventral nerve; this nerve passes to the hinder end of the body, sending off numerous nerves which are not regularly paired. A pair of simple eyes, pigmented or not, lies within the brain. A ciliated canal extending from the surface to the brain and called the cerebral tube, the walls of which are pigmented in certain species, is present just back of the tentacles: tactile organs are also often present. The sexes are separate, but alike in appearance. A pair of gonads develops in the peritoneum upon the base of the retractor muscles which discharge their products into the body cavity, whence they make their way to the outside through the nephridia. The young animal passes through an active free-swimming stage. The metamorphosis is not accompanied by any well-marked evidences of metamerism, and the adult worm is still trochophore-like, indicating that the animals are very primitive forms near the base of the annelid stem. The animals live in the sand and mud, which they swallow in large quantities. They are found in almost all parts of the world, mostly in shallow water. The class contains about 11 genera and over 100 species, 16 of which have been found on the east and 4 on the west coast of this country.

Key to the genera *Sipunculida* here described:

a_1 Longitudinal muscles divided into bundles (except *Phascolosoma gouldi*).
  b_1 Tentacular fold instead of tentacles: no papillae on trunk..1. SIPUNCULUS
  b_2 Isolated tentacles present.
    c_1 Tentacles encircle the mouth.....2. SIPHONOSOMA
    c_2 Tentacles in a crescent dorsal to mouth.....3. PHYSCOSOMA
a_2 Longitudinal muscles not split into bundles (with *Phascolosoma gouldi*).
  b_1 Worms free-living with numerous tentacles.....4. PHASCOLOSOMA
  b_2 Worms inhabit tubes or shells.....5. PHASCOLION

1. **SIPUNCULUS** L. Mouth surrounded by a fluted tentacular fold, without isolated tentacles, behind which is the cerebral tube; no hooks on the introvert; longitudinal muscles in 17 to 41 distinct bundles, giving a lattice-like effect; 4 retractor muscles; rectum with 1 or more cæca; 2 contractile hearts: 16 species, mostly of large size, in most seas.

S. nudus* L. (Fig. 445). Body up to 21 cm. long; the anterior sixth covered with papillae; 13 longitudinal muscles: Beaufort, North Carolina; Key West; Europe.

2. **SIPHONOSOMA** Spengel. Similar to *Sipunculus* but with integumental blind sacs and a statocyst near the tentacles; cerebral tube a shallow pit: several species.

* See "On Some Points on the Anatomy and Histology of Sipunculus nudus L.," by H. B. Ward, Bull. Mus. Comp. Zool., Vol. 21, p. 143, 1891.

S. cumanense (Keferstein). Longitudinal muscles 21; body cavity divided by septa into regular subdivisions as in an annelid; oral tentacles present: North Carolina; Florida; Philippines.

3. Physcosoma Selenka. Body covered with papillae; usually 4 retractor muscles; introvert with hooks arranged in rings; tentacles numerous, not surrounding the mouth but lying above it, forming a horseshoe; longitudinal muscles as in *Sipunculus;* eye spots present: about 27 species, mostly tropical.

Fig. 445—*Sipunculus nudus*—anterior end of body with the introvert extended (Ward).

P. agassizi Keferstein. Body up to 4 cm. long and 10 mm. thick; introvert as long as body; about 20 rows of broad hooks just back of tentacles, of which there are 20; 25 longitudinal muscles: Pacific coast, Vancouver to Panama.

4. Phascolosoma F. S. Leuckart. Longitudinal muscles usually not split up into bundles but forming a continuous sheath; mouth surrounded by one or more concentric circles of finger-shaped tentacles; 2 or 4 retractor muscles in the introvert: over 25 species, cosmopolitan, some species living in the shells of snails.

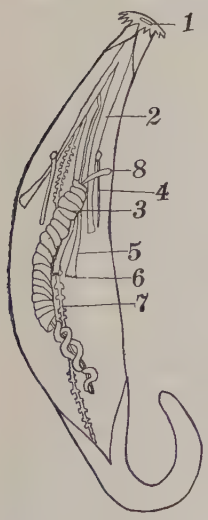

Fig. 446—Dissection of *Phascolosoma gouldi* (Kingsley). 1, mouth; 2, anterior retractor muscles; 3, intestine; 4, nephridium; 5, posterior retractors; 6, gonad; 7, nerve chord; 8, anus.

P. gouldi* (Pourtalès) (Fig. 446). Body with longitudinal muscles not forming a continuous sheath but split up into about 30 anastomosing bundles; length 18 cm., the anterior quarter of which is proboscis; skin smooth; tentacles very numerous, in several rows; a pair of pigmented ocular tubes open into the cerebral organ: Long Island Sound to Massachusetts Bay.

P. eremita (Sars). Body with transverse ridges, 2 to 5 cm. long and 5 to 12 mm. thick; introvert nearly as long as body, without hooks; 2 retractor muscles; no spindle muscle; 20 to 40 tentacles: Massachusetts coast northwards, in 40 to 1,000 fathoms; Arctic Ocean.

5. Phascolion Théel. Small forms living in tubes or in small shells; tentacles numerous, form-

* See "Notes in the Anatomy of the Sipunculus gouldii Pourtalès," by E. A. Andrews, Stud. Biol. Lab. Johns Hopkins Univ., Vol. 4, p. 389, 1890. "The Development of Phascolosoma," by J. H. Gerould, Zool. Jahrb. Abt. f. Anat., etc., Vol. 23, p. 77, 1906.

ing a single circle around the mouth; alimentary canal not spiral or incompletely so; no spindle muscle; 2 retractors; but 1 brown tube: 15 to 20 species.

P. strombi (Montagu) (Fig. 447). Body 30 mm. long, with papillae; a band of minute hooks back of tentacles, and large, dark-brown, crescentic or triangular hooks pointing forwards on the hinder part: common in 2 to 1,000 fathoms from the West Indies to the Arctic Ocean; Mediterranean; the worm lives in a snail shell, closing the aperture by means of sand cemented into a firm mass, leaving a hole through which the introvert is thrust out, and moves about carrying the shell with it; common, there being many varieties, some of which form a thick short tube of mud and sand.

Fig. 447
Phascolion strombi (Gerould).

Class 2. PRIAPULIDA.

Body without tentacles; anus at the hinder end; introvert plump and covered with rows of small spines; trunk striated transversely and in most species bearing 1 or 2 large caudal appendages with respiratory papillae; alimentary canal in most cases straight and wide; pharynx muscular, provided with numerous teeth; main nervous system subepithelial, consisting of a ring around the mouth and a ventral cord without definite ganglia; no special sense organs, blood-vascular system, or nephridia in the adult, but in the young worm nephridia are present which open into the genital ducts; sexes distinct; gonads paired; genital ducts open to the outside near the anus: 2 genera and 6 species, which are found in shallow water in the colder seas, where they burrow in the sand and mud.

Priapulus Lamarck. Caudal appendages, covered with hollow papillae present; introvert thicker than the trunk, about a quarter as long as it and with spines in longitudinal rows: 5 species.

P. caudatus Lam. Length 2 to 18 cm., color yellow or brown: Arctic seas.

PHYLUM IV.

ANNELIDA.* (The Annelid Worms.)

Elongated, segmented worms in which a distinct head, a cœlom, and a digestive tube are present, and the paired appendages, where present, are not segmented.

External Structure.—The segmentation, which is the most characteristic feature of annelids, is approximately equivalent (Fig. 461, A). This is the most pronounced in the *Chætopoda,* in which it affects both the inner and the outer structure, the segments or somites being separated from one another by muscular partitions called dissepiments; in the *Hirudinea* and the *Myzostomida* the internal structure is also completely segmented but the rings which appear on the outer surface may not mark the somites; in the *Echiurida* the larval worm alone is segmented.

A head is more or less distinctly marked in most annelids and contains the mouth, the brain, and also often tentacles, cirri and palps, which may have a tactile and often a respiratory function; eyes are also often present. The head is typically composed of two divisions (Fig. 459), the prostomium and the peristomium or metastomium. The first of these divisions is a distinct projection which forms the anterior end of the animal; it lies in front of the mouth (Fig. 450, A) and contains the brain and the eyes, tentacles, and palps, if these are present. The second contains the mouth, which is ventral in position, and often cirri, and is continuous with the segmented trunk, in many annelids appearing as a part of it.

Paired, segmental appendages, which in the annelids are muscular projections of the body wall and are called parapodia, are present in the *Polychæta* and the *Myzostomida,* and all annelids except the *Hirudinea,* most *Archiannelida,* and the *Discodrilidae,* possess paired, segmental groups of bristles, which are called setae and assist in locomotion. The parapodia are locomotory, respiratory, and tactile in function. The *Hirudinea* and a few other groups possess suckers, which assist in locomotion.

The outer surface of the body of annelids is a cuticula and is usually not ciliated in the adult worm.

* See "Invertebrate Animals of Vineyard Sound," by A. E. Verrill, Rep. U. S. Com. Fish. for 1871-72. "Preliminary Account of the Marine Annelids of the Pacific Coast," etc., by H. P. Johnson, Proc. Cal. Acad. Sci. (3), Vol. 1, 1897. "A Biological Survey of the Waters of Woods Hole and Vicinity," by F. B. Sumner, et al., Bull. Bur. Fish., Vol. 31, 1913.

Internal Structure.—The body wall consists of the cuticula, which forms the outer covering, the hypodermis, a single layer of cells which secretes the cuticula, and two layers of muscle fibers, an outer circular and an inner longitudinal layer. In the *Hirudinea* and *Myzostomida* the body cavity is filled more or less completely with a vacuolated connective tissue and muscle fibers, similar to the parenchyma of the *Plathelminthes.* In other annelids a spacious body cavity is present, which is usually divided by the dissepiments into as many separate spaces as there are somites.

The mouth leads into the pharynx (Fig. 487, 5), which in most annelids can be thrust out through the mouth to form a proboscis, and is the means by which the animal takes its food. An œsophagus is usually distinctly marked and is followed by the intestine, which in most cases is straight and passes to the anus at the hinder end of the body; in many annelids a pair of lateral intestinal pouches is present in each somite and a dorsal and a ventral longitudinal mesentery joins the intestine with the body wall.

A well-developed system of blood tubes (Fig. 487, 7) is present in all except the lowest annelids, which often carry red blood, the most important of which are a dorsal longitudinal tube just above the intestine, a ventral tube just beneath it, and transverse tubes placing these in communication with each other. The body cavity has also a circulatory fluid of its own which in many annelids is in open connection with the blood tubes.

The excretory system (Fig. 479, 6) consists typically of a pair of coiled tubes called kidney tubules or nephridia in each somite. Each nephridium opens into the body cavity by the ciliated nephrostome at one end and to the outside through a pore in the body wall at the other. Respiration is carried on through the entire outer surface of the body. In the *Polychæta,* however, special respiratory organs are present in the form of projections of the parapodia or the appendages of the head.

The nervous system (Fig. 479) consists of paired, segmental, ventrally situated ganglia and a pair of longitudinal nerves joining them. The anterior ganglionic mass constitutes the brain; it is dorsal in position, being situated above the pharynx in the prostomium. In their most primitive condition these two longitudinal nerves are separated from each other, but in most annelids they lie close together, forming a single strand. Special sense organs exist in a variety of forms. Tactile organs in the form of the paired appendages of the head and trunk characterize the polychæts and the *Myzostomida;* in the oligochæts and leeches the entire forward portion of the body is highly sensitive. Eyes are present in polychæts and leeches, and a few of the former also possess lithocysts.

In the unisexual annelids (most polychæts) the reproductive organs are not well marked except during the period of breeding, when they appear as specialized portions of the peritoneum. The hermaphroditic annelids on the other hand have a complicated system of reproductive organs (Fig. 479). The unisexual forms are mostly born in the form of the trochophore larva, which goes through a complicated metamorphosis before reaching the condition of the adult: in the hermaphroditic annelids, the development is usually direct, the young worm when born having the form of the parent. The body of the typical, primitive annelid may be divided into two portions, the prosoma, or the primitive head, and the metasoma, or the primitive segmented trunk. The trochophore larva, which in most cases is supposed to represent the prosoma alone, is a simple unsegmented animal, the metasoma not yet having made its appearance. The metasoma soon begins to grow, however, at the posterior end of the prosoma, the segments or somites developing one after the other as the worm increases in length, until in some cases a hundred and fifty or more may be present in the adult worm. In the higher annelids the prosoma annexes one or more of the anterior somites of the trunk and forms thus a head of increased size and complexity in which we can distinguish the two divisions already mentioned, the prostomium and the peristomium.

In the hermaphroditic annelids, which have a direct development, these processes go on in the egg and the young worm is born with its definitive form, although usually not with the full number of somites. Many annelids reproduce also asexually by transverse divisions or by serial or even lateral budding.

Distributions and Habits.—All annelids live in the water or in moist places on the land or in the earth, the majority being marine. Most of them are predaceous animals, although the oligochæts live chiefly on vegetable substances. The leeches are either predaceous or parasitic and the *Myzostomida* are exclusively parasitic.

History.—It was Cuvier who, in 1798, first called attention to the fundamental difference in structure between the higher and the lower worms, and Lamarck who gave the former the name *Annelides.* Savigny (1820) subdivided the group into the *Annelides nereideae, serpuleae, lumbricineae,* and *hirudineae,* and may be considered the founder of the modern classification. Milne-Edwards (1834) introduced the subdivisions *Annelides errantes, tubicoles,* and *terricoles,* which for sixty years or more had a place in the system, and Grube (1851) the subdivisions *Polychæta* and *Oligochæta,* which are still in general use. In more recent times Ehlers has been perhaps the most active in the development of the system.

The phylum contains about 4,500 species grouped in 4 classes.

Key to the classes of *Annelida:*

a_1 No suckers or sucker-like organs present (except in the *Discodrilidae*); segmentation usually distinct externally.
b_1 No setae (except in *Chætogordius*) or parapodia present.1. ARCHIANNELIDA
b_2 Setae present.....2. CHÆTOPODA
a_2 Suckers or sucker-like organs present.
b_1 Body ringed externally with a terminal sucker at each end; leeches. 3. HIRUDINEA
b_2 Body flat and oval in shape with 5 pairs of parapodia and 4 pairs of sucker-like organs; parasites on echinoderms.....4. MYZOSTOMIDA

CLASS 1. ARCHIANNELIDA.

Primitive, marine worms of small size, which are probably near the base of the line of the *Annelida,* having many characters which ally them to larval polychæts: 2 isolated, genetically unrelated families.

Key to the families of *Archiannelida:*

a_1 Body with 5 or 6 segments, marked by ciliated bands.....1. DINOPHILIDAE
a_2 Body with numerous segments.....2. POLYGORDIIDAE

FAMILY 1. DINOPHILIDAE.*

Minute, marine worms living among seaweed; body short, thick, and cylindrical, and made up of a head or prostomium, a trunk consisting of 5 or 6 segments, and a telson or tail; head with a pair of eyes, 2 bands of cilia and tactile bristles, no tentacles being present; each segment with 1 or 2 bands of cilia; ventral surface also ciliated; sexes separate and development simple, the worm becoming adult at a stage resembling a polychætous larva: 1 genus and about 9 species, 3 American.

Fig. 448 *Dinophilus conklini* (Nelson).

DINOPHILUS Schmidt. With the characters of the family.

D. pygmæus Verrill. Length .7 mm.; width .16 mm.; trunk segments 5; color whitish: Woods Hole, on piles.

D. gardineri A. Moore. Color orange red; trunk segments 6; body ciliated in addition to the ciliated bands: Woods Hole, in brackish pools.

D. conklini Nelson (Fig. 448). Length .5 to 1 mm.; colorless; trunk segments 6: New Jersey coast.

FAMILY 2. POLYGORDIIDAE.

Small, marine annelids in which the segmentation is completely equivalent and often indistinctly marked externally or not at all, and

* See "Dinophilidae of New England," by A. E. Verrill, Trans. Conn. Acad., Vol. 8, p. 457. "The Morphology of Dinophilus conklini n. sp.," by J. A. Nelson, Proc. Acad. Nat. Sci., Phila., Vol. 59, p. 82, 1907.

which have no parapodia and usually no segmental setae; head composed of prostomium and metastomium, the former lying in front of the mouth and bearing a pair of tentacles, the latter larger than the prostomium and without appendages; body cavity, digestive, excretory, and vascular systems typically annelidan in character; nervous system subjacent to the hypodermis and without distinct ganglia; animals unisexual, the genital products developing from specialized regions of the peritoneum during the breeding season; young born as trochophore larvae: 2 or 3 genera; the larvae are common in the plankton at many places along the Atlantic coast, but with the exception of *Chætogordius* no adult worms have been found.

Fig. 449
Larva of *Polygordius appendiculatus* (Cowles).

1. Polygordius Schneider. Body filiform; segmentation indistinct at the forward end but more distinct at the hinder; tentacles short; anal segment enlarged: about 6 species.

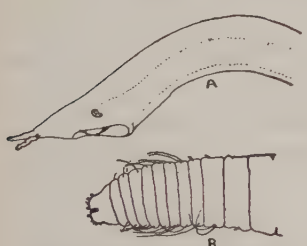

Fig. 450—*Chætogordius canaliculatus* (original drawings by J. P. Moore). A, anterior end; B, posterior end.

P. appendiculatus* Fraipont (Fig. 449). Length 20 mm.; body salmon color; 2 long anal appendages present: Atlantic coast (only larval forms heretofore found); Mediterranean.

2. Chætogordius† Moore. Segmentation as in *Polygordius;* hindermost 10 or 12 segments setigerous; no anal enlargement: 1 species.

C. canaliculatus Moore (Fig. 450). Length 30 mm.: among marine oligochæts on Cape Cod.

Class 2. CHÆTOPODA.‡

Segmentation distinct, except in the *Echiurida,* both internally and externally; setae segmentally arranged in groups on the parapodia, where these are present, or sunk in pits on the integument: 3 orders.

* See "On the Rearing of the Larvae of Polygordius appendiculatus and the Occurrence of the Adult on the Atlantic Coast of America," by R. P. Cowles, Biol. Bull., Vol. 4, p. 125, 1903.

† See "A New Generic Type of Polygordius," by J. P. Moore, Am. Nat., Vol. 38, p. 519, 1904.

‡ See "Annelida Chætopoda of New Jersey," by H. E. Webster, Thirty-second Rep. N. Y. St. Mus. Nat. Hist., p. 128, 1879. "New England Annelids," by A. E. Verrill, Trans. Conn. Acad., Vol. 4, p. 285, 1881. "The Annelida Chætopoda from Provincetown," etc., by H. E. Webster and J. E. Benedict, Rep. Com. Fish. for 1881, p. 699, 1884. "The Annelida Chætopoda from Eastport, Maine," by same, same jour. for 1885, p. 707, 1887. "The Annelida Chætopoda of Beaufort, N. C.," by E. A. Andrews, Proc. U. S. Nat. Mus., Vol. 14, p. 277, 1891. "Polychæta of the Puget Sound Region," by H. P. Johnson, Proc. Bost. Soc. Nat. Hist., Vol. 29, p. 381, 1902.

Key to the orders of *Chætopoda:*

a_1 Segmentation distinct.
b_1 Parapodia with complex groups of setae; usually cephalic appendages present; mostly marine.....1. POLYCHÆTA
b_2 No parapodia or cephalic appendages present; mostly fresh-water or terrestrial.....2. OLIGOCHÆTA
a_2 Segmentation indistinct or wanting in adult; marine.....3. ECHIURIDA

ORDER 1. POLYCHÆTA.

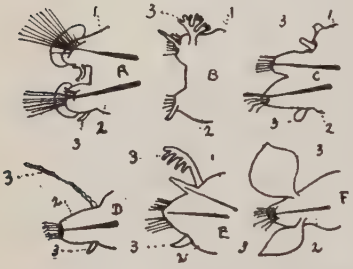

Fig. 451—Diagram of parapodia (Cambridge Natural History). A, Nephthys; B, Amphinome; C, Glycera; D, Syllis; E, Leodice; F, Phyllodoce. 1, notopodium; 2, neuropodium; 3, cirrus.

Mostly marine annelids, either free-swimming or sedentary, which are provided with parapodia. Two portions may usually be distinguished in the parapodium (Fig. 451), the dorsal notopodium and the ventral neuropodium, both of which may contain setae; two cirri, a dorsal and a ventral, extend from it. In the sedentary polychæts the parapodia are much reduced in size on either the whole or a part of the body and in a few they are entirely wanting.

The polychæts have a distinct head which is usually provided with special sense organs (Fig. 452). The prostomium may bear tentacles, which may number from one to ten and are dorsal in position, and two palps which are ventral and in certain forms are broken up into long respiratory filaments. Elongated peristomial cirri may also be present. Eyes are often present on the prostomium and lithocysts are found in a few forms (*Arenicola*). The mouth is in the peristomium and is often provided with a proboscis. Polychæts are often highly colored; bright red, green, blue, and yellow tints characterize many of them and make them very beautiful animals.

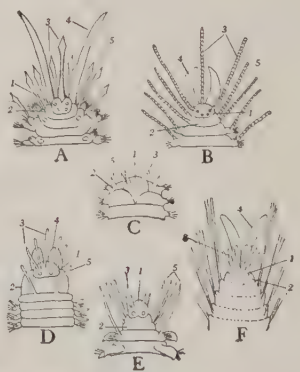

Fig. 452—Diagram of the heads of various polychæts (Cambridge Natural History). A, polynoid; B, syllid; C, Nephthys; D, Leodice; E, Phyllodoce; F, Trophonia. 1, prostomium; 2, peristomium; 3, tentacles; 4, palps; 5, peristomial cirri.

Polychæts are usually born as trochophore larvae and pass through a metamorphosis before reaching the adult stage. Many reproduce asexually by serial or even lateral

budding. In many the anterior part of the body is sexless and is called the atoke, while the hinder part is sexual and is called the epitoke, these two portions being different in appearance; in some the epitokes break off from the atokes and swim about independently, while the atokes bud off new epitokes. The palolo worm of the Samoan and Fiji Islands is the epitoke of *Leodice viridis,* which comes to the surface in great numbers at the full of the October moon to breed, and which are caught by the natives for food. The palolo worm of the Atlantic is *L. fucata.* In *Syllis* the epitoke forms a new head; in *Autolytus* this happens before separation.

In certain species of *Nereis* heterogony is present, a small pelagic form alternating with a large one which lives at the bottom.

Distribution and Habits.—A very few polychæts live in fresh water (*Manayunkia* in the Schuylkill, a *Nereis* in California, and several others); the remainder, which are marine, are almost all bottom animals which burrow in the sand or in rocks or live in tubes they have built for themselves of lime or other material. They are found at all depths and are usually numerous in all parts of the world. The free-swimming polychæts are predaceous animals, while the sedentary ones live on all kinds of organic substances; a few are parasitic, and a number commensalistic.

The order contains about 39 families and 2,500 species grouped in 7 suborders.

Key to the suborders of *Polychæta:*

a_1 Worms free-swimming or burrowing, a few tubicolous; head distinct, with tentacles and palps.....1. NEREIDIFORMIA
a_2 Worms tubicolous or burrowing; head not so distinct and not provided with both tentacles and palps; sometimes with neither.
b_1 Peristomium does not project forwards in form of a collar.
c_1 Head with gill filaments (except in *Cirratulidae*)....3. TEREBELLIFORMIA
c_2 Head without gill filaments.
d_1 One pair of long peristomial cirri present.....2. SPIONIFORMIA
d_2 One pair of retractile tentacle-like organs on head..4. CAPITELLIFORMIA
d_3 Head with no appendages (except in *Chlorhæmidae*)....5. SCOLECIFORMIA
b_2 Peristomium projects forward in form of a collar.
c_1 Peristomial collar not setigerous.....6. SABELLIFORMIA
c_2 Peristomial collar setigerous.....7. HERMELLIFORMIA

SUBORDER 1. NEREIDIFORMIA.*

Well-developed tentacles and palps present; peristomial cirri almost invariably present; parapodia well developed, with internal skeletal rods called acicula and ventral and dorsal cirri; proboscis present, often with prehensile hooks; worms predacious, a few forming tubes: about 13 families.

* See "Die Borstenwürmer," by E. Ehlers, 1864.

Key to the families of *Nereidiformia* here described:

a_1 Back partially or totally covered with broad, overlapping scales. 1. APHRODITIDAE

a_2 Back without these scales.

b_1 Dorsal cirri broad and leaf-like, overlapping one another, but not covering the back.....2. PHYLLODOCIDAE

b_2 Cirri not broad and leaf-like.

c_1 Dorsal cirri usually long and slender; asexual budding usual..3. SYLLIDAE

c_2 Dorsal cirri not very long; asexual reproduction unusual.

d_1 Prostomium not annulated.

e_1 No large teeth or jaws on proboscis.

f_1 Proboscis simple; parapodia usually uniramous.....4. HESIONIDAE

f_2 Proboscis divided into lobes; prostomium small and acute..9. ARICIIDAE

e_2 Two or more large teeth or jaws usually on proboscis.

f_1 But 1 pair of jaws; 1 pair of tentacles, 1 pair palps and 4 pairs peristomial cirri.....5. NEREIDAE

f_2 Two or more pairs of jaws.

g_1 One pair of dorsal and 1 pair of ventral jaws.....6. NEPHTHYDIDAE

g_2 Jaws form a complicated apparatus.....7. LEODICIDAE

d_1 Prostomium annulated; tentacles inconspicuous; proboscis very large. 8. GLYCERIDAE

FAMILY 1. APHRODITIDAE. (FIG. 452, A.)

Worms with imbricated scales (elytra) on the back, mostly on alternate segments, which may take the place of dorsal cirri; slender dorsal cirri usually alternate with the scales; head with usually 3 tentacles and 2 long palps: numerous genera and species.

Fig. 453
Aphrodita hastata (Moore).

Key to the genera of *Aphroditidae* described:

a_1 Body with felt-like bristles on sides and back concealing the elytra.....1. APHRODITA

a_2 Body without this felt.

b_1 Body with but few pairs of elytra.

c_1 Prostomium prolonged into the base of the lateral tentacles; 12 pairs of elytra. 2. LEPIDONOTUS

c_2 Prostomium produced forward into a pair of pointed tips, quite free from the base of the tentacles.....3. HARMOTHOË

b_2 Body with numerous pairs of elytra.

c_1 Over 40 pairs present.....4. PHOLOË

c_2 Over 100 pairs present.....5. STHENELAIS

1. APHRODITA L. Body elliptical, with 15 pairs of elytra; entire back covered by the long felt-like setae arising from the notopodium; strong dorsal setae also present, projecting through the felt; 1 short tentacle and 2 long palps on the head: about 15 species, 2 in the Woods Hole region.

A. hastata Moore (Fig. 453). The Sea Mouse. Body short, wide, and thick, the sides and back covered with the iridescent felt; dorsal

setae curve over the back to the middle line where they end in hooks; length 12 cm.; width 4 cm.: Vineyard Sound, in from 10 to 100 fathoms.

2. **Lepidonotus** Leach. Body broad, with nearly parallel sides, and 12 pairs of elytra; head with 3 tentacles, 2 long palps, and 2 pairs of peristomial cirri; eyes sessile: under stones near tide lines; 2 New England species.

Fig. 454 *Lepidonotus squamatus* (Verrill).

L. squamatus (L.) (Fig. 454). Elytra tuberculated; color dark brown; length about 3 cm.; width 8 mm.: very common from New Jersey to Labrador; Europe.

L. sublevis Verrill. Elytra smooth; color light brown or gray, with spots; length about 3 cm.; width 7 mm.: Virginia to Massachusetts; not so common as the above.

3. **Harmothoe** Kinberg. Body flattened and elongate, with 15 pairs of elytra; head bilobed and with 3 tentacles, 2 long palps, 2 pairs of peristomial cirri and 4 eyes; segments completely or nearly covered by elytra: 2 New England species.

H. imbricata (L.). Color variable, grayish or brownish, sometimes with a black dorsal stripe; 42 to 44 segments; 2 to 3 cm. long: Long Island to Greenland; from low-water mark to 60 fathoms; Europe; North Pacific.

H. aculeata Andrews (Fig. 455). Surface covered with spines; 34 segments; length up to 2 cm.: the commonest scale annelid at Beaufort, N. C.; under stones, etc., in shallow water.

Fig. 455

Fig. 456

Fig. 455—*Harmothoë aculeata*—head with extended proboscis (Andrews). 1, proboscis; 2, palp; 3, tentacles; 4, peristomial cirri; 5, prostomium. Fig. 456 — *Pholoë minuta* (Leunis).

4. **Pholoe** Johnston. Body with less than 70 segments and with numerous pairs of elytra which alternate with the dorsal cirri anteriorly but occur on every segment posteriorly; 2 pairs eyes; 2 short peristomial cirri; 1 tentacle: several species, 1 in New England.

P. minuta (Fabricius) (Fig. 456). Number of segments in adult about 68; number of pairs of elytra 44; length 2 cm.: Cape Cod, and northwards; in shallow water; Europe; North Pacific.

5. **Sthenelais** Kinberg. Elongated worms with numerous segments (over 100) and but 1 tentacle; 2 pairs eyes; elytra very numerous, alternating with dorsal cirri anteriorly but on every segment posteriorly: many species, 2 in the Woods Hole region.

S. leidyi Quatrefages (*S. picta* Verrill). More than 150 pairs of elytra present; color grayish with a mid-dorsal stripe; head brown with a central red spot and a white spot on each side; length 15 cm.; width 4 mm.: North Carolina to Massachusetts Bay, in shallow water.

Family 2. PHYLLODOCIDAE. (Fig. 452, E.)

Elongated, active polychæts with broad, leaf-like dorsal and ventral cirri which do not cover the back; prostomium with 4 or 5 short tentacles and 2 or 4 eyes; peristomium with usually 4 long cirri on each side; proboscis with longitudinal rows of prominent papillae: about a dozen genera with numerous species.

Key to the genera of *Phyllodocidae* here described:

a_1 Four pairs of peristomial cirri present.
  b_1 Four tentacles ..... 1. Phyllodoce
  b_2 Five tentacles ..... 2. Eulalia
a_2 Two pairs of peristomial cirri ..... 3. Eteone

1. Phyllodoce Savigny. Body long, slender, and flattened, with 4 tentacles on the prostomium, and often a pair of rudimentary parapodia on the peristomium together with the cirri: about 60 species, 7 in New England.

P. grönlandica Oersted. Color green or yellowish with irregular brown markings; usual length 10 to 15 cm.: New Jersey to Greenland, from low-water mark to 50 fathoms.

P. catenula Verrill. Color pale green with longitudinal rows of brown spots on the back; prostomium longer than broad, with a pair of large brown eyes; tentacles short; peristomial cirri very long; length up to 7 cm.; width 1.5 mm.: Rhode Island to Bay of Fundy and northwards, from low-water mark to 50 fathoms; common.

2. Eulalia Oersted. Body slender and flattened, with 5 tentacles on the prostomium and 4 pairs of peristomial cirri: 7 species in New England.

E. pistacia Verrill. Color bright yellowish-green; body slender; tentacles short; peristomial cirri long; length 4 cm.; width 1.5 mm.: Long Island Sound to Maine, in 4 to 12 fathoms, among hydroids, etc.

3. Eteone Oersted. Body slender, flattened with 4 tentacles and 2 pairs of cirri on somite 2 which is fused with the peristomium: 4 species in New England.

E. alba Webster. Color white; length 40 mm.: on mussel beds; New Jersey to Cape Cod.

Family 3. SYLLIDAE. (Fig. 452, B.)

Elongated worms, mostly under an inch in length, with usually very long slender dorsal cirri, which may be flattened; prostomium with 3

tentacles, 2 palps, and 4 eyes; peristomium with 2 cirri on each side; reproduction normally by asexual budding: numerous species; abundant in clean, shallow water among hydroids, mussels, and tunicates.

Key to the genera of *Syllidae* here described:

a_1 Palps prominent; ventral cirri present; tentacles and cirri segmented. 1. SYLLIS

a_2 Palps rudimentary; ventral cirri absent; tentacles and cirri filiform. 2. AUTOLYTUS

1. SYLLIS Savigny. Tentacles and cirri segmented, the latter often terminally dilated; palps large; new individuals formed by terminal, and in case of *Syllis ramosa,* lateral budding: numerous species, 2 in the Woods Hole region.

S. pallida Verrill. Body slender, tapering at both ends, 15 to 25 mm. long; color white: Long Island Sound to Bay of Fundy; in mud, sand, and on shells, from low-water mark to 30 fathoms.

2. AUTOLYTUS* Grube. Tentacles and cirri not segmented; palps rudimentary or absent; ventral cirri wanting; the young individual acquires a head before separating from the parent, and a number may be present in a row; males and females differ in appearance: numerous species, 6 in the Woods Hole region.

A. cornutus A. Agassiz. Length 15 mm.; color pinkish; full-grown male having 30 segments, female 40 to 50 segments: New Jersey to Bay of Fundy, from low-water mark to 15 fathoms; common.

Fig. 457

Fig. 458

Fig. 457 — *Autolytus varians* (Mensch). 1, tentacles; 2, peristomial cirri; 3, budding individuals. Fig. 458—*Podarke obscura* (Verrill).

A. varians Verrill (Fig. 457). Length 15 mm.; intestine with bright-red spots which can be seen through the body wall: North Carolina to Maine, often among hydroids.

FAMILY 4. HESIONIDAE.

Body rather short and often cylindrical; parapodia usually uniramous and with long, jointed dorsal setae; 4 eyes, 2 or 3 tentacles, and 2 palps on the prostomium; peristomium with long cirri: species not numerous.

* See "Autolytus," by P. C. Mensch, Jour. Morph., Vol. 16, p. 269, 1900.

Podarke Ehlers. Six pairs of long cirri on the peristomium and first two somites: several species.

P. obscura Verrill (Fig. 458). Color variable, usually brown or blackish, sometimes with transverse bands; length up to 4 cm.; width, including setae, 3 mm.: Gulf of Mexico to Cape Cod; on eel grass and under stones; abundant.

Family 5. NEREIDAE. (Fig. 459.)

Elongated polychæts with 2 small tentacles, 2 palps, 4 eyes on the prostomium, and 4 pairs of peristomial cirri; proboscis with 2 large jaws; parapodia well developed: several genera.

Fig. 459—Head of a nereid. 1, prostomium; 2, tentacles; 3, palp; 4, peristomial cirri; 5, peristomium.

Nereis L. Clam worms. Body elongate and flattened; in some species during the sexual period the hinder part (epitoke) of the animal with the sexual products differs from the forward part (atoke) in appearance and the animal is called a heteronereis: numerous species, 7 in the Woods Hole region.

N. virens Sars. Large worms, flesh-colored, with a greenish sheen; jaws black; dorsal division of notopodium foliaceous; length up to 30 cm. or more; width 1 cm.: common from Long Island Sound to Labrador, buried in the sand near the low-water mark; breeding season spring; Europe.

N. limbata Ehlers (Fig. 460). Color brownish; jaws light amber-colored; dorsal division of notopodium foliaceous; length up to 15 cm.: Maine to South Carolina; in the sand from high-water mark to 5 fathoms; abundant south of Cape Cod.

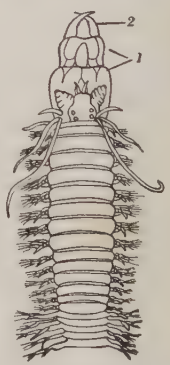

Fig. 460 *Nereis limbata*—anterior end with extended proboscis (Verrill). 1, proboscis 2, jaws.

N. pelagica L. Color reddish-brown; body widest in the middle; dorsal division of notopodium conical; length up to 20 cm.; width 8 mm.: Virginia to Greenland; on hard bottoms from low-water mark to 100 fathoms; Europe; North Pacific.

N. limnicola* Johnston. Color reddish-brown; length 47 mm.; width 3 mm.; eyes large and conspicuous: in fine sand in Lake Merced (fresh water) near San Francisco.

* See "Fresh-water Nereids from the Pacific Coast and Hawaii," etc., by H. P. Johnston, Mark Ann. Vol., p. 205, 1903.

Family 6. NEPHTHYDIDAE.

Elongated polychæts with flattened dorsal and ventral surfaces, giving a quadrangular cross section; prostomium with 4 small tentacles, the ventral pair being modified palps; peristomium with parapodia bearing setae and a pair of short cirri; proboscis very large with long fleshy projections in front; the two lobes of the parapodia widely separate: few genera and species.

Nephthys Cuvier (Fig. 452, C). Characters as given above: numerous species, 4 in the Woods Hole region.

N. incisa Malmgren (*N. ingens* Stimpson). Proboscis with large dorsal and small ventral papillae; length 13 cm.; color white: Long Island Sound to Bay of Fundy and northwards, from below low-water mark to 60 fathoms, on muddy bottoms; Europe; common.

N. bucera Ehlers (*N. picta* Ehl.). Body slender with over 100 segments; setae very long, often exceeding in length the diameter of the body; forward tentacles longer than half the width of head; length 20 cm.; width 5 mm.: South Carolina to Massachusetts Bay, in shallow water in sand, and among rocks.

Family 7. LEODICIDAE.

Elongated polychæts with a complicated jaw apparatus in the proboscis; the cirri of the anterior parapodia form branching gills in most species; prostomium either with 3 to 5 tentacles and a pair of palps or without cephalic appendages; usually a permanent parchment-like tube formed: about 30 genera with several hundred species.

Key to the genera of *Leodicidae* here described:

a_1 Gills present.
  b_1 Peristomium consisting of 1 segment and with cirri; gills branched. 2. Diopatra
  b_2 Peristomium consisting of 2 segments.
    c_1 Gills branched. 1. Leodice
    c_2 Gills simple 3. Marphysa
a_2 Gills absent.
  b_1 Head without appendages.
    c_1 Eyes absent 4. Lumbrinereis
    c_2 Four eyes in a transverse row 5. Arabella
  b_2 Head with appendages 6. Stauronereis

1. Leodice Savigny (*Eunice* Cuvier) (Fig. 452, D). Body elongate with numerous segments; peristomium consists of 2 segments with 1 pair of cirri; 5 tentacles and 2 large palps present; gills begin usually on sixth segment: species very numerous, 2 in the Woods Hole region, in rather deep water. To this genus belong the largest known polychæts, the largest species having a length of 1 m. and more.

L. fucata* Ehlers. Atlantic palolo worm (Fig. 461). Length up to 35 cm., the atokal portion being about two-thirds the whole; color brownish or yellowish: West Indies and Gulf of Mexico; living in coral rock and swarming within 3 days of the full of the July moon.

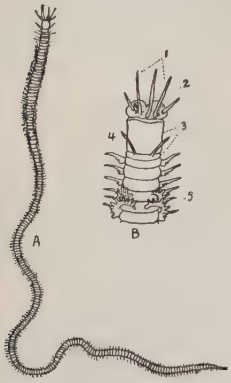

Fig. 461—*Leodice fucata* (Mayer). A, entire worm; B, head end. 1, tentacles; 2, palp; 3, peristomium; 4, peristomial cirri; 5, gills.

2. Diopatra Ehlers. Peristomium with 1 pair of cirri; 5 tentacles in a transverse curved line and 2 small palps present; gills beginning several segments back from the head: many species, 1 in New England.

D. cuprea (Bosc) (Fig. 462). Large worms up to 30 cm. long and 10 mm. wide which live in parchment-like tubes extending 2 or 3 feet in the sand, the upper 2 or 3 inches of the tube projecting into the water and thickly covered with shells, etc.: common in shallow water and between tide lines; from South Carolina to Cape Cod.

3. Marphysa Quatrefages. Peristomium consists of 2 segments, and is without cirri; 5 tentacles in a transverse row, 2 small palps and 2 eyes present; gills begin about the 20th segment but are variable in this respect: 1 species at Woods Hole.

M. leidyi Quatr. (*M. sanguinea* Leidy) (Fig. 463). Length 20 cm.; color yellowish or brownish-red; tubes not so perfect as those of preceding worms: under stones and in the sand in shallow water; from North Carolina to Vineyard Sound.

4. Lumbrinereis Blainville (*Lumbriconereis* Ehlers). Head conical, without appendages or eyes; peristomium consisting of 2 segments; dorsal cirri flat, and parapodia small: many species, 5 at Woods Hole.

L. tenuis (Verrill). Body filiform up to 30 cm. long, with the diameter of a coarse thread, bright red in color: Virginia to Massachusetts; burrowing in mud and under stones.

Fig. 462

Fig. 463

Fig. 462—*Diopatra cuprea*—ventral view of anterior end (Verrill). 1, tentacles; 2, peristomial cirrus. Fig. 463—*Marphysa leidyi*—anterior end (Verrill).

5. Arabella Grube. Similar to *Lumbrinereis* but with usually 4 eyes in a transverse row on the prostomium: several species, 2 in the Woods Hole region.

* See "The Annual Breeding-Swarm of the Atlantic Palolo," by A. G. Mayer, Carnegie Inst., Wash., Pub. 102, 1908.

A. opalina (Verrill) (Fig. 464). Body cylindrical, largest in the middle, reddish or yellowish in color, up to 40 cm. long, and 3 mm. wide: North Carolina to Maine; burrowing in muddy sand; common; West Indies.

6. Stauronereis Verrill. Prostomium small and quadrangular with 2 tentacles and 2 palps; gills not present, the dorsal cirri being long and slender: several species, 1 in the Woods Hole region.

S. pallidus Verr. Two pairs of eyes present; color pale yellow; length 5 cm.; width .7 mm.: Virginia to Cape Cod; in the sand at low-water mark.

Fig. 464 *Arabella opalina*—anterior end (Verrill).

Family 8. GLYCERIDAE.

Elongated cylindrical worms with usually small parapodia, and an annulated prostomium which bears 4 small tentacles and 2 rudimentary palps; proboscis very large and long, with 4 teeth; special retractile gills present either on the body wall or the parapodia: about 5 genera; the worms live in cylindrical passages in the sand, which they make with the proboscis.

Key to the genera of *Glyceridae* here described:

a_1 Parapodia of same structure throughout.....1. Glycera
a_2 Parapodia with 1 lobe on anterior third of body and 2 lobes on posterior portions.....2. Goniada

1. Glycera Savigny. Parapodia of the same structure throughout: several species, 3 at Woods Hole.

G. dibranchiata Ehlers (Fig. 465). Length 20 cm.; prostomium sharp and conical; both dorsal and ventral gills large, simple, and flat: from North Carolina to Bay of Fundy and northwards; in shallow water, burrowing very rapidly in sand and mud; often very common.

Fig. 465—*Glycera dibranchiata* — anterior end (Verrill). 1, prostomium.

G. americana Leidy (Fig. 466). Length 20 cm.; width 4 mm.; dorsal gills branched; ventral gills absent: from South Carolina to Cape Cod; in shallow water; not so common as *G. dibranchiata.*

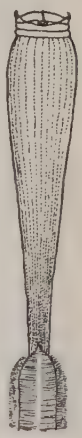

Fig. 466 *Glycera americana*—anterior end with proboscis extended (Verrill).

2. Goniada Audouin and Edwards. Parapodia on the first third of the body with a single lobe, on hinder part with 2 lobes: several species, 2 in New England.

G. maculata Oersted. Body slender with about 194 segments; the first 40 parapodia 1-lobed, the following 2-lobed; 2 principal teeth;

length 10 cm.: Maine coast, from low-water mark to 30 fathoms, in rock and sand; Europe.

Family 9. ARICIIDAE.

Usually cylindrical worms with short knob-like tentacles and palps, or none at all, and with filiform gills which are more or less dorsal in position: the worm forms a tube by cementing the sand around its burrow, the position of which can be detected by a mound at the opening; species not numerous.

1. **Aricia** Savigny. Body short and composed of many small segments; tentacles and peristomial cirri absent; ventral cirri fimbriate or pectinate: several species, 1 at Woods Hole.

A. ornata Verrill. Body stout and somewhat flattened; gills flattened, lanceolate, and begin on the sixth segment; length up to 26 cm.; width 7 mm.: North Carolina to Cape Cod; in shallow water.

2. **Scoloplos** Blainville. Body usually elongate and fragile, without tentacles or peristomial cirri; proboscis lobulate: several species, 3 at Woods Hole.

S. robustus (Verrill). Large worms 30 cm. long and 7 mm. wide, with an acute head and small anterior parapodia; elongate gills begin on segment 26; proboscis divided into about 18 long slender lobes; color yellowish-brown: in shallow water, from North Carolina to Cape Cod.

S. fragilis (Verr.). Body 12 cm. long, 3 mm. wide; head acute, with a 6-lobed proboscis; the gills begin to appear in segment 16; color yellowish: between tide lines; from North Carolina to Maine.

Suborder 2. SPIONIFORMIA.

Neither tentacles nor palps present; 1 pair of long peristomial cirri usually present; parapodia small, the dorsal cirri often large and forming gills; proboscis without jaws; worms burrowing or tubicolous: 2 families.

Family 1. SPIONIDAE.

Small burrowing worms with a pair of long peristomial cirri which usually curve over the back; dorsal cirri acting as gills; proboscis present, but unarmed; body divided into 2 regions: in tubes in the sand, or burrowing in wood or shells; species not numerous.

Key to the genera of *Spionidae* here described.

a_1 Segment 5 not enlarged.
  b_1 Gills on hinder half of body.....1. Spio
  b_2 Gills absent on hinder half of body.....2. Laonice
a_2 Fifth segment different from the others.....3. Polydora

1. **Spio** Fabricius. Segments alike throughout; head with a prominent median lobe which may be truncated or divided in front; 4 eyes; gills on all the segments: several species, 2 at Woods Hole.

S. setosa Verrill (Fig. 467). Body long, flattened above and rounded below; parapodia 2-lobed; color green; gills and cirri red; length 8 cm.; width 2.5 mm.: Long Island and Vineyard Sounds; at low-water mark.

2. **Laonice** Malmgren. Segments alike throughout; prostomium with 2 or 4 eyes, very broad in front; gills absent from hinder half at least of body: several species, 2 at Woods Hole.

Fig. 467
Spio setosa—side view of anterior end (Verrill). 1, peristomial cirrus.

L. (*Scolecolepis* Blainville) **viridis** (Verrill). Body flattened; color olive green or brownish; length 10 cm.; breadth 3 mm.: Long Island and Vineyard Sounds; near low-water mark; often common.

3. **Polydora** Bosc. Fifth segment different from the others, being much longer and with characteristic setae: many species, 7 at Woods Hole.

P. concharum Verrill. Body long and slender, being 14 cm. long and 1.5 mm. wide, with 200 segments; color grayish or yellowish: very common from Cape Cod to Nova Scotia; in 10 to 100 fathoms, often burrowing in shells.

Family 2. CHÆTOPTERIDAE.

Worms living in U-shaped parchment-like tubes up to 50 cm. long, buried in the sand and mud; 3 distinct regions in the body; no tentacles or palps present and but 1 pair of peristomial cirri which tend to project backwards; proboscis wanting: few genera and species.

Chætopterus Cuvier. Parapodia simple, consisting of large, expanded notopodia in the anterior body region, but may be biramous in the other two regions: 15 species, 1 at Woods Hole.

C. pergamentaceus Cuv. Body short and stout; anterior region much flattened; middle region composed of 1 segment with large wing-like parapodia and 4 swollen segments; body walls very thin, intestine and genital products showing through; highly phosphorescent; length 15 cm.: North Carolina to Cape Cod; Europe.

Suborder 3. TEREBELLIFORMIA.

Prostomium a prominent lobe with or without tentacular filaments which represent the tentacles and without palps; peristomium with or without cirri; parapodia weak, without ventral cirri, the dorsal cirri

sometimes acting as gills on the anterior or all segments; no proboscis or jaws present: 4 families; worms burrowing or tubicolous.

Key to the families of *Terebelliformia:*

a_1 Head without appendages.....1. CIRRATULIDAE
a_2 Head with long tentacular filaments.
b_1 Tentacular filaments very long.
c_1 No setae on head.....2. TEREBELLIDAE
c_2 A bundle of setae on each side of head.....3. AMPHARETIDAE
b_2 Tentacular filaments short.....4. AMPHICTENIDAE

FAMILY 1. CIRRATULIDAE.

Small and medium-sized cylindrical worms which are usually found in burrows or under stones; head distinct but without appendages or proboscis; parapodia rudimentary, but dorsal cirri very long and filamentous and acting as gills: several genera.

Fig. 468—*Cirratulus grandis* (Verrill). 1, dorsal cirri.

CIRRATULUS Lamarck. Head conical; cirri very long and slender, a pair of them being present on almost every segment; a transverse row of long branchial filaments on one of the anterior segments: many species, 4 at Woods Hole.

C. cirratus (O. F. Müller). Head consists of a prostomium and a peristomial segment; a row of eyes on the prostomium; length 8 cm.; width 4 mm.: coast of Maine; in tubes under stones; Europe.

C. grandis Verrill (Fig. 468). No eyes present; first 3 segments without cirri; color yellowish-green; length 15 cm.; width 6 mm.; length of longest cirri 6 to 10 cm.: Virginia to Cape Cod; in sand and gravel, in shallow water; common.

FAMILY 2. TEREBELLIDAE.

Long and often thick worms living in burrows or tubes; head with a prominent horseshoe-shaped preoral lobe whose anterior margin is reflexed, behind which is a transverse ridge bearing large numbers of long tentacular filaments which act as gills; behind these are usually 1 to 3 pairs of branching gills belonging to the anterior segments; parapodia reduced; both capilliform and hooked setae: numerous species.

Key to the genera of *Terebellidae* here described:

a_1 Worms not filamentous; branching gills present.
  b_1 Three pairs of branching gills present.
    c_1 Capilliform setae only on anterior somites.....1. AMPHITRITE
    c_2 Capilliform setae also on posterior somites.....4. LEPRÆA
  b_2 Two pairs of branching gills.
    c_1 Capilliform setae begin on segment 4.....2. PISTA
    c_2 Capilliform setae begin on segment 3.....5. THELEPUS
  b_3 But 1 gill, which has 4 branches.....3. TEREBELLIDES
a_2 Worms filamentous and blood red; no branching gills.
  b_1 Parapodia simple.....6. POLYCIRRUS
  b_2 Parapodia elongated and branched.....7. ENOPLOBRANCHUS

1. AMPHITRITE O. F. Müller. Body cylindrical, thickest towards the forward end; 3 pairs of branching gills; setae begin on the 4th segment and confined to anterior part of body; no eyes: many species, 4 in the Woods Hole region.

A. ornata (Leidy) (Fig. 469). Color pinkish; length up to 30 cm., with about 40 setigerous segments; tentacular filaments very long, numerous, and contractile: North Carolina to Cape Cod, at low-water mark; common, living in firm tubes which are sometimes cast up on the beach.

Fig. 469
Amphitrite ornata (Verrill).
1, tentacular filaments
2, gills.

A. brunnea (Stimpson). Color dark reddish-brown; segments about 100, 25 of which have setae; each gill with 7 to 12 branches; length up to 18 cm.: north of Cape Cod at low-water mark, in deeper water towards the south.

2. PISTA Malmgren. Two pairs of branching gills; setae begin on the 4th segment and extend to the 20th; no eyes; first 3 somites with large ventral and lateral wings: 3 species in the Woods Hole region.

P. palmata (Verrill). Body rather slender, with 17 setigerous segments; color reddish-brown; length 7 cm.; width 2 mm.; animal constructs tubes of bits of shell, etc.: Long Island and Vineyard Sounds.

3. TEREBELLIDES Sars. Two pairs of gills present which are large and form 4 wide, comb-like branches on a single peduncle; tentacular filaments numerous (over 100): 1 species in the Woods Hole region.

T. strœmi Sars. Body with about 60 segments and reddish in color; length 7 cm.; width 5 mm.: Vineyard Sound to Bay of Fundy; in 10 to 250 fathoms; Europe.

4. **Lepræa** Malmgren. Three pairs of branching gills; setae begin on 4th segment and extend the length of the body: several species, 1 in the Woods Hole region.

L. rubra Verrill. Body elongate, swollen anteriorly; color bright red; length 5 cm.; width 3 mm.: North Carolina to Vineyard Sound; in tubes on shells, etc., below low-water mark.

5. **Thelepus** Leuckart. Two pairs of branching gills; setae begin on the 3rd segment and continue nearly or quite to the hinder end; eyes numerous: 1 species in the Woods Hole region.

T. cincinnatus (Fabricius). Setae extend almost to the hinder end of the body; eyes present; length up to 12 cm.; color yellowish or reddish: coast of Maine to Vineyard Sound; in tubes often covered with shells; Europe.

6. **Polycirrus** Grube. Blood worms. Very long, slender worms with bright-red blood; no branching gills: several species, 2 in the Woods Hole region.

P. eximius (Leidy). Body bright red with about 100 segments, of which 25 bear setae: North Carolina to Cape Cod; in sand and mud in shallow water; very common.

P. phosphoreus Verrill. Brilliantly phosphorescent worms when disturbed; length 8 cm.; first 24 segments bear setae: Long Island Sound to Bay of Fundy.

7. **Enoplobranchus** Verrill. Blood worms. Body flattened; setae extending to the hinder end of the body; with branched parapodia in the middle division: 1 species.

E. sanguineus (Verr.). Body very long and slender; branched parapodia begin on segment 12; color bright red; length 35 cm.; width 7 mm.: Virginia to Gulf of St. Lawrence; common at low-water mark; in mud and sand.

Family 3. AMPHARETIDAE.

Similar to the previous family; a bundle of setae present on each side of the head in front of the gills; tentacular filaments small and not numerous; no branched gills, but 4 pairs of filamentous ones present: several genera.

Ampharete Malmgren. Tentacular filaments few in number; gills on 3rd and 4th segments: numerous species, 2 in Woods Hole region.

A. setosa Verrill. Body thick anteriorly, tapering backwards; 40 tentacular filaments; color light green or red; length 20 mm.; width 3 mm.: Long Island and Vineyard Sounds; in rough tubes in shallow water.

Family 4. AMPHICTENIDAE.

Small worms which form tubes of sand open at both ends which can be carried about by their occupants; the prostomium bears short filamentous tentacles which are protected by long yellow setae; hinder end of the worm without parapodia and folded on the forward part: several genera and few species.

Pectinaria Malmgren. Characters as given above: several species, 2 in the Woods Hole region.

P. gouldi (Verrill) (Fig. 470). Body flesh-color, mottled; length 4 cm.; width 7 mm.: North Carolina to Maine; in shallow water.

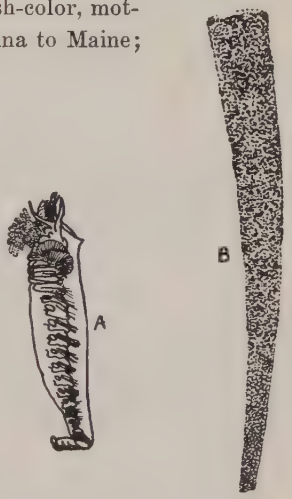

Fig. 470—*Pectinaria gouldi* (Verrill). A, the worm; B, its tube.

Suborder 4. CAPITELLIFORMIA.

Head pointed and not distinctly set off, without tentacles or palps but with a pair of ciliated, retractile, tentacle-like organs; parapodia rudimentary, with sessile capilliform setae on the anterior and sessile hook-like ones on the posterior segments; proboscis without jaws: 1 family.

Family CAPITELLIDAE.

With the characters of the suborder: several genera.

1. **Notomastus** Sars. Prostomium conical, without eyes; body composed of 2 portions, a forward thicker part (thorax) consisting of about 12 biannulated segments, and a long hinder portion: several species, 3 in Woods Hole region.

N. luridus Verrill. Long, cylindrical worms, 15 cm. long, 2 mm. thick; color dark brown: Long Island Sound to Maine; at low-water mark in tubes in muddy sand.

N. filiformis Verr. Body filiform, 10 cm. long, 1 mm. thick; color pale red, often mottled with whitish: Long Island and Vineyard Sounds; at low-water mark.

2. **Capitella** Blainville. Large genital setae on 8th and 9th segments; thorax consisting of 9 segments; only the middle portion of the body with setae: several species, 1 in Woods Hole region.

C. gracilis (Verrill). Length 5 cm.; color red; head triangular: Cape Cod to Bay of Fundy; in tubes in the mud in shallow water.

Suborder 5. SCOLECIFORMIA.

Head without appendages (except in the *Chlorhæmidae*); parapodia poorly developed or absent; proboscis present but unarmed: 6 families.

Key to the families of *Scoleciformia* here described:

a_1 Head without appendages.
  b_1 Segmentation equivalent; body not made up of different regions. 1. Opheliidae
  b_2 Segmentation not equivalent; body made up of 2 or 3 more or less distinct regions.
    c_1 Worms slender and without gills ..... 2. Maldanidae
    c_2 Worms thick, with branching gills on the middle segments .. 3. Arenicolidae
a_2 Head with appendages ..... 4. Chlorhæmidae

Family 1. OPHELIIDAE.

Small burrowing worms which occur in shallow water; head without appendages but with a proboscis; parapodia rudimentary, the dorsal cirri of which are elongate and act as gills: about 6 genera.

Fig. 471 *Ammotrypane fimbriata* (Verrill).

Ammotrypane Rathke. Head conical and acute; ventral side flattened: 1 species at Woods Hole.

A. fimbriata Verrill (Fig. 471). Body elongate, being thickest in advance of the middle and tapering to both ends; color purplish; length 7.5 cm.; width 3 mm.: Vineyard Sound to Maine; in shallow water.

Family 2. MALDANIDAE.

Slender, cylindrical worms which live in sand tubes; head formed of the fused prostomium and peristomium and usually obliquely truncated by a cephalic plate and without appendages; parapodia rudimentary, with setae but without gills; hinder end funnel-shaped, usually with frilled edges: 7 genera.

Key to the genera of *Maldanidae* here described:

a_1 Anus dorsal to caudal funnel ..... 1. Maldane
a_2 Anus in center of caudal funnel.
  b_1 Anal funnel without cirri ..... 2. Clymenella
  b_2 Anal funnel with cirri ..... 3. Nicomache

1. **Maldane** Grube. Body elongate, truncated at both ends, most of the segments being biannulated; anus dorsal: numerous species, several in the Woods Hole region.

M. urceolata (Leidy) (*M. elongata* Verrill). Body elongate with 19 setigerous segments, the middle ones being much elongated; color reddish-brown; length 30 cm.; width 5 mm.: in sandy mud at low-water mark; North Carolina to Cape Cod.

2. Clymenella Verrill. Body with 18 or more setigerous segments and with obliquely truncated head: several species, 2 in the Woods Hole region.

C. torquata (Leidy) (Fig. 472). Body with a membranous collar arising near the middle of the 4th setigerous segment; 22 segments, 18 with setae; color reddish; length 10 cm.: North Carolina to Bay of Fundy; in sand from low-water mark to 60 fathoms.

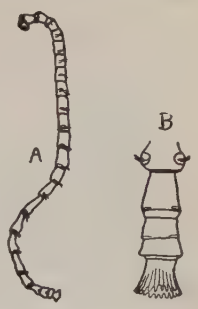

Fig. 472 — *Clymenella torquata* (Leidy). A, entire worm B, hinder end.

3. Nicomache Malmgren. Funnel-shaped terminal segment with marginal cirri; head without truncating plate; prostomium sharply bent downwards: several species.

N. lumbricalis (Fabricius). Body slender and fragile, consisting of 26 segments; color pink; length 7 cm.: Cape Cod and northwards; Europe.

Family 3. ARENICOLIDAE.

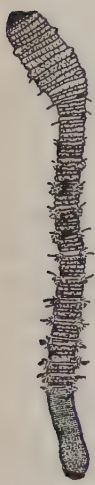
Fig. 473 *Arenicola marina* (Cambridge Natural History).

Elongated worms which burrow deep in the sand; head without appendages, with an unarmed proboscis; peristomium with a pair of lithocysts; parapodia rudimentary, with branching gills above them in the middle of the body: 1 genus.

Arenicola Lamarck. Anterior end blunt, the prostomium and peristomium being fused together; body cylindrical, thickest at the forward end: few species, 2 in the Woods Hole region.

A. marina (L.) (Fig. 473). Segmentation indistinct, the skin being annulated; about 21 setigerous segments present, of which 8 compose the anterior and 13 the middle region, but only 4 dissepiments and 6 pairs of nephridia; length up to 20 cm.; diameter 8 mm.: Long Island Sound northwards; in deep burrows in the sand; rare south of Cape Cod; Europe.

A. cristata Stimpson. Head very small; middle branchiate region with 11 pairs of gills; color greenish-yellow; length 35 cm. or more: Florida to Cape Cod.

Family 4. CHLORHÆMIDAE. (Fig. 452, F.)

Rather small worms which live in burrows and under stones; body not divided into regions; whole head retractile and with a circle of 3 to

20 pairs of green, short tentacular filaments which act as gills; palps large; proboscis unarmed; blood green; setae of the anterior segments often very long and projecting directly forwards: 6 genera.

Fig. 474
Trophonia affinis—anterior end (Verrill).

1. Trophonia Milne-Edwards. Anterior setae prolonged, enclosing the head: 2 species in the Woods Hole region.

T. affinis (Leidy) (Fig. 474). Body slender and elongate; 8 tentacular filaments on head, which are blunt and of unequal length; length 6 cm.; width 3.5 mm.: Vineyard Sound and New Jersey; in 20 fathoms.

Suborder 6. SABELLIFORMIA.*

Prostomium more or less hidden by the forward extension of the peristomium which usually forms a projecting collar; tentacles rudimentary or very small; palps very large, forming the branchial crown; proboscis present; body consisting of 2 regions, a thorax of about 9 segments, and an abdomen; worms tubicolous: 4 families.

Key to the families of *Sabelliformia* here described:

a_1 Tubes membranous.....1. Sabellidae
a_2 Tubes calcareous.....2. Serpulidae

Family 1. SABELLIDAE.

Worms which live in membranous tubes in mud and sand; arising from the prostomium is a pair of large semi-circular feathered gills representing the palps, which may be surrounded by a collar formed of the peristomium; tentacles rudimentary or hidden; parapodia very rudimentary: many genera.

Key to the genera of *Sabellidae* here described:

a_1 Peristomial collar present.
  b_1 Collar lobes separated dorsally.....1. Sabella
  b_2 Collar lobes meeting dorsally.....2. Potamilla
a_2 Collar absent.
  b_1 Worms live in gelatinous masses; no eyes.....3. Myxicola
  b_2 Worms live in distinct tubes; eyes present.
    c_1 Worms in fresh water.....4. Manayunkia
    c_2 Worms marine.....5. Fabricia

1. Sabella Malmgren. Gill filaments long and slender; peristomium raised and reflexed to form a collar around the gills which is notched dorsally: many species.

* See "Tubicolous Annelids of the Tribes Sabellides and Serpulides from the Pacific Ocean," by K. J. Bush, Harriman Alaska Exp., Vol. 12, 1910.

S. microphthalma Verrill. Body short, composed of about 60 segments; anterior region composed of 8 setigerous segments; gill filaments with minute eye spots; color greenish-yellow; length 5 cm.; diameter 3 mm.: North Carolina to Cape Cod; at low-water mark, often incrusted on oyster shells, etc.

2. **Potamilla** Malmgren. About 12 to 30 gill filaments on each side, some of which have eyes at the base; peristomial collar without a dorsal notch: several species.

P. oculifera (Leidy) (*P. reniformis* Malm.). Length 8 cm.; color greenish or reddish-brown: New Jersey to Bay of Fundy; on shells in tide pools; Europe.

3. **Myxicola** Koch. Body thick; hinder region with numerous hooks in transverse rows; gill filaments united by a membranous web; without eyes on head; eye spots on terminal segment; 2 small tentacles: worms live in gelatinous masses attached to shells, etc., in which each worm has a separate tube; several species.

M. steenstrupi (Kröyer). Body thick, with about 60 segments, of which 8 belong to the anterior body region; color pink; length 6 cm.; width 5 mm.: north of Cape Cod; Europe.

4. **Manayunkia** Leidy. About 36 gill filaments with eyes at their bases; body composed of but few segments: 1 species; in fresh water.

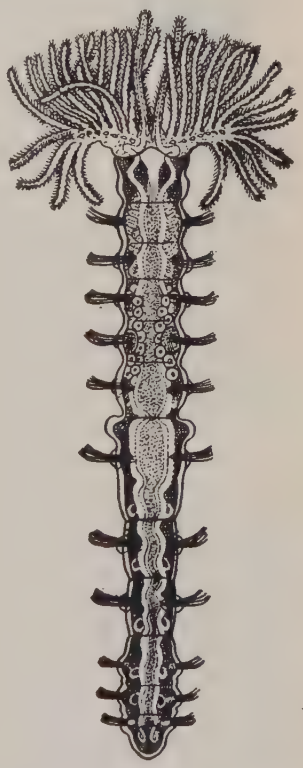

Fig. 475
Manayunkia speciosa (Leidy).

M. speciosa Leidy (Fig. 475). Body 4 mm. long and consisting of 12 segments, and yellowish-brown in color: in tubes on stones in Schuylkill River, Philadelphia, also in Egg Harbor River, New Jersey, associated with *Urnatella gracilis*.

5. **Fabricia** Blainville. But few gill filaments or tentacles; body composed of but few segments: few species, 1 in the Woods Hole region.

F. leidyi Verrill. Body 3 mm. long and .2 mm. wide, consisting of 13 segments and yellowish-brown in color; 6 gill filaments: Long Island Sound to Bay of Fundy; in slender tubes, at and below low-water mark.

Family 2. SERPULIDAE. (Fig. 476.)

Worms which live in calcareous tubes; arising from the prostomium are a pair of large semicircular feathered gills which represent the palps; an operculum usually present, composed of the dorsal gill filaments; just beneath the gill filaments is the collar, a paired membrane employed in smoothing the inside of the shell: numerous genera and species.

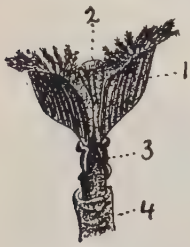

Fig. 476—A serpulid projecting from its tube (Cambridge Natural History). 1, gills; 2, operculum; 3, collar; 4, tube.

Key to the genera of *Serpulidae* here described:

a_1 Tubes incrusted on shells, etc.....1. Hydroides
a_2 Tubes minute, spiral, usually on seaweed or shells. 2. Spirorbis
a_3 Tubes intertwining.....3. Filograna

1. Hydroides Gunnerus. Small worms living in long contorted tubes incrusted on shells, etc.; funnel-shaped operculum present: several species, 1 in Woods Hole region.

H. hexagonus Bosc (*H. dianthus* Verrill) (Fig. 477). Color of gills variable, oftenest a purplish-brown; length 75 mm.; diameter 3 mm.: Florida to Cape Cod; very common.

2. Spirorbis Daudin. A small worm living in a tube coiled usually in a flat spiral, which is incrusted on seaweeds, etc.; operculum present: many species, 6 in the Woods Hole region.

S. spirorbis (L.) (*S. borealis* Daudin). Coiled tube 3 mm. across; length of animal 3 mm.; 9 gill filaments present; color of gills greenish-white: Long Island Sound to Bay of Fundy and northwards.

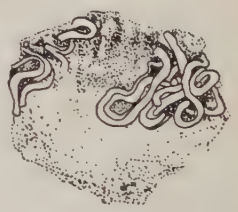

Fig. 477
Hydroides hexagonus (Hargitt) on a shell.

3. Filograna Oken. Small worms living in slender white tubes which intertwine, forming masses 7 cm. high; 8 gill filaments present: 1 species in Woods Hole region.

F. implexa Berkeley. Body compressed, 4 mm. long; tubes very thin; color purple or pink: Maine to Vineyard Sound; Europe.

Suborder 7. HERMELLIFORMIA.

Peristomium very much enlarged and forming a setigerous bilobed hood enclosing the prostomium, which bears a pair of tentacles and a pair of palps; the latter are fused with the ventral edges of the peristomium and project in the form of numerous gill filaments from the hood; body composed of 2 regions, a thorax and a long tail-like abdomen which has no parapodia and folds back on the thorax: 1 family and few species.

FAMILY HERMELLIDAE.

With the characters of the suborder: 3 genera.

SABELLARIA Lamarck. With the characters of the suborder: several species, 1 at Woods Hole.

S. vulgaris Verrill. Color yellowish or reddish; length 3 cm.; width 2.5 mm.: North Carolina to Cape Cod; from low-water mark to 10 fathoms; common in tubes of sand, also on shells.

ORDER 2. OLIGOCHÆTA.*

Mostly fresh-water or terrestrial, hermaphroditic annelids which are without parapodia and cephalic appendages (Fig. 478). The setae are few in number and project from pits in the body wall; in the *Discodrilidae* and *Anachæta* they are wanting. Some oligochæts have external gills (a few naids and tubificids). The head is small and consists of the prostomium, which is a small projection in front of the mouth, and the peristomium, which contains the mouth and often appears dorsally like the first somite of the trunk, but differs from the somites in that it has no setae.

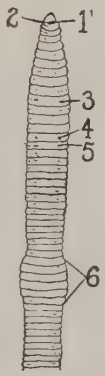

Fig. 478

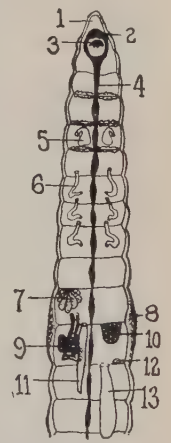

Fig. 479

Fig. 478—Diagram of the anterior portion of an earthworm, *Lumbricus terrestris* (Sedgwick and Wilson). 1, prostomium; 2, mouth; 3, openings of the spermathecae; 4, openings of the oviducts; 5, openings of the sperm ducts; 6, clitellum. Fig. 479—Diagram of the anterior portion of an oligochæt (an enchytræid), showing the internal organs with the digestive tract and the right-hand male organs and the left-hand female organs removed (Galloway). 1, prostomium; 2, brain; 3, mouth; 4, ventral nerve chord; 5, spermathecae; 6, nephridium; 7, testis; 8, clitellum; 9, sperm duct; 10, ovary; 11, sperm sac; 12, oviduct; 13, egg sac.

Paired ovaries and testes are present (Fig. 479); a number of large sperm sacs or vesiculae seminales act as reservoirs of the sperm, in which the sperm ripens as it comes from the testes, and one or more pairs of pockets called the receptacula seminis or spermathecae receive the sperm of another animal during the act of pairing. The eggs and sperm are extruded into a capsule called the cocoon which is secreted by a thickened portion of the integument called the clitellum. Development is direct, the young animal being born with the form of the parent; of the numerous eggs in a cocoon only a few, sometimes only one, hatch out. Many oligochæts reproduce asexually, by transverse division, and the regenerative powers of all are great.

* See "A Monograph of the Order Oligochæta," by F. Beddard, 1893. "Notes on Species of North American Oligochæta," by F. Smith, Bull. Ill. St. Lab., Vol. 4, p. 285, 1895. "Notes on Species of N. A. Oligochæta, II," by same, same jour., Vol. 4, p.

Oligochæts are poorly provided with special sense organs. Pigment eyes are present in certain naids; tactile cells and processes may be present but tentacles never are. The forward part of the body of earthworms is especially sensitive to light and other stimuli.

The terrestrial oligochæts are the earthworms. These familiar animals are often of large size, the largest being six feet in length, and are found in temperate and tropical countries in all parts of the world. They are nocturnal animals which live in burrows in the soil and feed on decaying vegetation and the organic particles in the soil, which they pass in large quantities through the intestine. Darwin has estimated that an acre of ordinary ground will have about 63,000 earthworms which bring many tons of earth to the surface from a foot or two beneath. They are thus important agents in renewing the surface soil.

The aquatic oligochæts live mostly at the bottom of fresh-water streams and ponds, although a few live in the sea, often in tubes of mud or sand, and eat aquatic vegetation. The order contains over 1,200 species and about 11 families.

Key to the families of *Oligochæta* here described:

a_1 Worms microscopic.....1. Æolosomatidae
a_2 Worms not microscopic.
  b_1 Parasitic worms with terminal sucker.....2. Discodrilidae
  b_2 No sucker present.
    c_1 Worms very long and filiform.....3. Haplotaxidae
    c_2 Worms not so formed.
      d_1 Worms usually very small and slender and mostly aquatic.
        e_1 Reproduction mostly by serial budding, animal chains being formed. 5. Naididae
        e_2 Such reproduction not present, or at least uncommon.
          f_1 Spermatheca far forward, usually opening in segment 4 or 5.
          f_2 Spermatheca farther back. 4. Enchytræidae
            g_1 Setae usually more than 2 in a bundle and usually of more than one form.....6. Tubificidae
            g_2 Setae paired and all of one form.....7. Lumbriculidae
      d_2 Worms large and mostly terrestrial; earthworms.
        e_1 Clitellum begins before segment 18 and contains the male pores.
          f_1 Male pores in hinder margin of clitellum or entirely behind it. 8. Megascolicidae
          f_2 Male pores in forward portion of clitellum.....9. Geoscolecidae
        e_2 Clitellum begins at or behind segment 18; male pores some distance in front of it.....10. Lumbricidae

396, 1895. "Notes on Species," etc., by same, same jour., Vol. 5, p. 441, 1900. "Notes on Species of N. A. Oligochæta, IV," by same, same jour., Vol. 5, p. 459, 1900. "Oligochæta," by W. Michaelsen, Das Tierreich, 1900. "Researches in American Oligochæta," etc., by G. Eisen, Proc. Cal. Acad. Sci., 3d Ser., Zool., Vol. 2, 1900. "Hirudinea and Oligochæta Collected in the Great Lake Region," by J. P. Moore, Bull. U. S. Fish. Com., Vol. 25, p. 155, 1905. "Some Marine Oligochæta of New England," by J. P. Moore, Proc. A. N. S., Phila., 1905, p. 373. "Die Süsswasserfauna Deutschlands," Heft 13, "Oligochæta," by W. Michaelsen, 1909. "The Common Freshwater Oligochæta of the United States," by T. W. Galloway, Trans. Am. Mic. Soc., Vol. 30, p. 285, 1911.

Family 1. ÆOLOSOMATIDAE.

Microscopic fresh-water worms usually with brown, red, or yellow oil globules in integument, giving them a spotted appearance; no dissepiments present; setae in 4 bundles in each segment, of 1 to 6 setae each; clitellum only on ventral side on segments 5 to 7; nervous system hypodermic; prostomium ciliated ventrally; the most primitive oligochæts, reproducing by division: 1 genus.

Fig. 480
Æolosoma quaternarium (Cambridge Natural History).

Æolosoma Ehrenberg. With the characters of the family: about 9 species, 5 in this country.

A. quaternarium Ehr. (Fig. 480) (*A. venustum* Leidy). Head of same width as body; setae sharply bent, those of the same bundle of the same length; the worm encysts itself; spots red; length 1 mm., with 7 to 10 segments: among algae.

A. hemprichi Ehr. Head broader than body; setae nearly straight; spots red or crimson; length 2 to 5 mm., with 4 to 13 segments: among algae.

Family 2. DISCODRILIDAE.

Small parasitic oligochæts which were formerly grouped with the *Hirudinea,* with a sucker at the hinder end of the body and without setae, which live on the gills or the outer surface of crayfish; mouth with a dorsal and a ventral chitinous jaw; anus dorsal; 2 pairs of nephridia; 1 or 2 pairs testes; single median genital pore in sixth segment: several genera.

Key to the genera of *Discodrilidae* here described:

a_1 One pair testes.....1. Branchiobdella
a_2 Two pairs testes.
b_1 No dorsal appendages.....2. Bdellodrilus
b_2 Dorsal appendages present.....3. Pterodrilus

1. Branchiobdella* Odier. Dorsal and ventral jaws similar; 1 pair testes in fifth segment: 3 American species.

B. pulcherrima Moore. Body 6 mm. long and 1.3 mm. wide, very transparent forward and somewhat flattened; eighth and ninth segments flattened, each with a pair of adhesive organs: North Carolina.

B. instabilia Moore. Body 5.5 mm. long, 1.3 mm. wide; hinder 4 segments forming a flattened disc-shaped expansion which is almost as wide as long, anterior segment very contractile: eastern states.

* See "On Some Leechlike Parasites of American Crayfishes," by J. P. Moore, Proc. Ac. Nat. Sci., Phila., 1893, p. 419. "Notes on Branchiobdella," by W. M. Smallwood, Biol. Bull., Vol. 11, p. 100, 1906.

2. **Bdellodrilus** Moore. Two pairs of testes and sperm ducts: 2 species.

B. illuminatus (Moore) (Fig. 481). Body 4 mm. long and .9 mm. wide, the head being composed of 4 segments, the trunk of 11, all being biannulated; clitellum is the dorsum of segment 6: often common on the gills of crayfish; cocoons also on the gills; eastern North America.

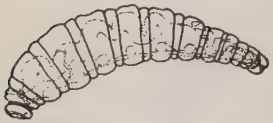

Fig. 481
Bdellodrilus illuminatus (Moore).

B. philadelphicus (Leidy). Head the broadest part of the body; length 10 mm.: on the external (usually the ventral) surface of crayfish; eastern and central North America.

3. **Pterodrilus** Moore. Two pairs of testes and sperm ducts; long paired, dorsal appendages on certain of the body segments: 2 species.

P. distichus Moore (Fig. 482). Dorsal appendages not branched; length 1 mm.: on the external surface of the crayfish in western New York.

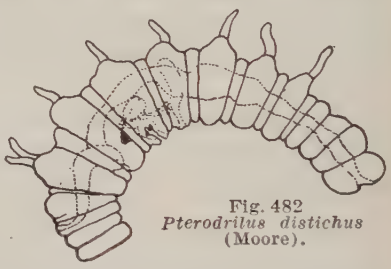

Fig. 482
Pterodrilus distichus (Moore).

Family 3. HAPLOTAXIDAE.

Body very long and slender or filamentous; setae sigmoid, single or paired, in 4 rows; 2 pairs of ovaries; central blood vessel contractile: 2 genera and 3 species.

Fig. 483
Haplotaxis gordioides (Süssw. F. Deut.).

Haplotaxis Hoffmeister. Clitellum on segments 11 to 14; 2 pair male pores on segments 11 and 12: 2 species.

H. gordioides Hartmann (*H. emissarius* Forbes) (Fig. 483). Dorsal setae absent on the hinder four-fifths of body; length 18 cm. and more; width .6 mm.; 375 segments: in wet ground or in the water (Illinois; Philadelphia).

Family 4. ENCHYTRÆIDAE.*

More or less slender worms 30 mm. or less in length which live in fresh water along the shore of the sea or in decaying or living plants; setae hair-like, in 4 bundles in each segment; clitellum when fully developed occupies segments 11 to 13; dorsal blood vessel arises near the clitellum; testes and ovaries in segments 11 and 12: about 13 genera and 170 species.

* See "Enchytræidae of the West Coast of North America," by G. Eisen, Harriman Alaska Exp., Vol. 12, 1910.

Key to the genera of *Enchytræidae* here described:

a_1 Setae straight, or nearly so.
  b_1 All setae in a bundle of equal length.....1. ENCHYTRÆUS
  b_2 Setae not all of equal length, inner setae of each bundle smaller than outer .....2. FRIDERICIA
a_2 Setae sigmoid.
  b_1 Blood yellow or red; testes massive.....2. LUMBRICILLUS
  b_2 Blood usually colorless; testes subdivided.....4. MESENCHYTRÆUS

1. ENCHYTRÆUS Henle. Setae straight or nearly so, all those in a bundle of equal length (Fig. 484); blood colorless; large salivary glands present: 10 species.

E. albidus Henle. Milk-white worms 25 mm. long and 1 mm. thick; setae nearly straight but hooked at inner end 2 to 6 in a bundle; number of segments 53 to 69: New Jersey to Maine, along the seashore near high-water mark under decaying seaweed and stones, also inland near the shore; very common in Europe and America.

E. socialis Leidy. Body translucent and 20 mm. long; setae 5 to 7 in a bundle; mouth triangular: in groups, in rotten stumps and logs.

Fig. 484

Fig. 485

Fig. 486

Fig. 484—Setae of *Enchytræus* (Süssw. F. Deut.). Fig. 485—Setae of *Lumbricillus* (Süssw. F. Deut.). Fig. 486—Setae of *Fridericia* (Süssw. F. Deut.).

2. LUMBRICILLUS Oersted (Fig. 485). Setae sigmoid; testes massive; blood yellow or red; no salivary glands; clitellum covers segments 11 and 12: 15 species.

L. agilis Moore. Transparent worms with pink or brown internal organs, 16 mm. long and .4 mm. thick: Maine to Vineyard Sound, along the seashore under seaweed near high-water mark.

3. FRIDERICIA Michaelsen (Fig. 486). Setae straight, 2 to 6 in a bundle and not of equal length, the inner setae of a bundle being shorter than the outer; blood colorless; salivary glands present: 21 species, 6 in this country.

F. alba Moore. Length 22 mm.; number of segments 58; spermatheca simple; salivary glands branched; setae long and slender: in wet moss and leaves in the woods.

F. parva Moore. Length 16 mm.; number of segments 46; spermatheca and salivary glands unbranched; 4 setae in a bundle as far as

segment 25, then 2; color opaline white: among damp leaves, in the woods.

F. agilis Smith. Length 30 mm.; number of segments 57 to 66; dorsal blood vessel begins at segment 19; salivary glands much branched: in the soil (Illinois).

4. **Mesenchytræus** Eisen. Setae sigmoid: blood usually colorless; no salivary glands: 30 species.

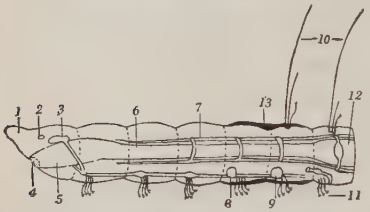

Fig. 487—Diagram of anterior portion of a naid (Walton). 1, prostomium; 2, eye; 3, brain; 4, mouth; 5, pharynx; 6, œsophagus; 7, blood vessel; 8, testis; 9, ovary; 10, hair-like setae; 11, forked setae; 12, intestine; 13, clitellum.

M. beumeri (Michaelsen). Length 30 mm.; setae 3 to 5 in lateral bundles and 5 to 8 in ventral ones; clitellum on segments 11 to 13: Philadelphia, in wet places; Europe.

Family 5. NAIDIDAE.*

Small aquatic, transparent worms (Fig. 487) with 2 to 4 groups of setae on each segment, and often with a distinct head; ventral setae forked; testes and ovaries usually in segments 5 to 7; the worms reproduce principally by transverse division, forming animal chains: 15 genera and 50 species, mostly in fresh water.

Key to the genera of *Naididae* here described:

a_1 Hair-like setae present dorsally.
  b_1 Prostomium not tentacular.
    c_1 Without retractile rear appendages.....1. Nais
    c_2 Retractile rear appendages present.....4. Dero
  b_2 Prostomium long and tentacular.
    c_1 Dorsal setae begin on 5th or 6th segment.....2. Stylaria
    c_2 Dorsal setae begin on 2d segment.....5. Pristina
a_2 Hair-like setae absent dorsally.
  b_1 No dorsal setae present.....6. Chætogaster
  b_2 Forked dorsal setae present.....3. Paranais

1. Nais O. F. Müller. Head distinct; dorsal setae begin on segment 6 and are partly acicular and partly long and hair-like; ventral setae short, with cleft ends; blood yellow or red; eyes usually present: in standing or flowing water, in mud or on plants; reproduction by budding very common; 10 species, 5 American.

N. elinguis Müll. (N. *rivulosa* Leidy). Two or 3 dorsal hair-like setae present; length 2 to 10 mm., with 15 to 37 segments; color light brown; eyes usually present: often abundant on algae; Europe.

N. parvula Walton. Prostomium blunt; eyes present; dorsal bundle composed of 1 hair-like and 2 cleft setae; length 1.2 mm.: Cedar Point, Lake Erie.

* See "Naididae of Cedar Point," by L. B. Walton, Am. Nat., Vol. 40, p. 683, 1906.

2. Stylaria Lamarck. Prostomium very long and tentacle-like; setae as in *Nais:* 2 species, in Europe and America.

S. lacustris (L.) (Fig. 488). Length 15 mm., with 25 segments: common; Europe.

3. Paranais Czerniavsky. Head distinct; setae all forked; dorsal setae begin on segment 5; no eyes: 3 species.

P. litoralis (O. F. Müller) (*Enchytræus triventralo-pectinatus* Minor). Length 10 mm.; segments about 20; blood greenish-yellow: Long Island and Vineyard Sounds, under stones or decaying vegetation near high-water mark on the seashore, also in fresh water; often very common; Europe.

Fig. 488
Stylaria lacustris (Walton).

4. Dero Oken. Setae as in *Nais;* ciliated branchial appendages extend from the funnel-shaped rear end; blood reddish; no eyes: 15 species, 4 in America; often in tubes.

D. limosa Leidy. Length 12 mm. or less with about 48 segments; color reddish: in tubes at the bottom of stagnant pools and among algae; common; Europe.

D. obtusa Udekem. Length 10 mm.; a long and a short seta in each dorsal bundle: Illinois; Europe.

Fig. 489

Fig. 490

Fig. 489
Dero vaga (Walton).
Fig. 490
Pristina serpentina (Walton).

D. vaga Leidy (Fig. 489). Length 8 mm.; number of segments 25 to 35; body ending in 2 long finger-like processes: often very common.

5. Pristina Ehrenberg. Dorsal setae all hair-like and begin in second segment; ventral setae all forked; prostomium very long and retractile; rear end sometimes with long projections; no eyes: 8 species, 3 American.

P. leidyi Smith. Length 8 mm., diameter .15 mm., with about 30 segments; 3 setae in each dorsal bundle, 5 to 9 in each ventral bundle; clitellum on segments 7 to 9: in streams and lakes in the eastern and central states; common.

P. serpentina Walton (Fig. 490). Length 2.2 mm. with about 22 segments; dorsal bundle with 5 to 9 setae, ventral bundle with 5 or 6: very common; Cedar Point, Lake Erie.

6. Chætogaster von Baer. Very transparent worms with 2 bundles of hooked setae on the ventral side of each segment and no dorsal setae; blood colorless: 6 species, 5 American.

C. limnæi von Baer (Fig. 491). Anterior bundles of setae with 10 to 20 each; length 5 mm.: eastern states, usually found on *Lymnæa* and *Planorbis* or parasitic in their liver; also free-living; common; Europe.

C. pellucidus Walton. Setae forked, 6 to 7 in a bundle; length 1.5 mm.: Cedar Point, Lake Erie; common.

Fig. 491—*Chætogaster limnæi* (Süssw. F. Deut.)

FAMILY 6. TUBIFICIDAE.

Slender, red or brown worms living in fresh or brackish water in tubes from which they protrude the hinder end; 4 bundles of setae on each segment; testes and ovaries in segments 10 or 11; but 1 pair of sperm ducts; no reproduction by division; clitellum on segments 11 and 12: about 14 genera and 50 species.

Key to the genera of *Tubificidae* here described:

a_1 Dorsal setae both forked and hair-like.....1. TUBIFEX
a_2 Dorsal setae all forked.
b_1 Setae of segment 11 modified.....3. BOTHRIONEURUM
b_2 These setae not modified.
c_1 No blood capillaries in body wall.....2. CLITELLIO
c_2 Capillaries in body wall.....4. LIMNODRILUS

1. TUBIFEX Lamarck. Forked and usually hair-like setae in the dorsal bundles; usually forked setae alone in the ventral bundles; contractile hearts in segment 8: several species.

T. irroratus (Verrill) (*Clitellio irroratus* Verr.). Pink or brown worms 3 cm. long; prostomium acute: near high-water mark south of Cape Cod on the seashore.

T. benedeni Udekem. Gray or black worms; cuticula studded irregularly with flattened papillae; length 4 cm.: Long Island Sound to Maine, near high-water mark on the seashore.

Fig. 492—*Tubifex tubifex*—forked setae with middle teeth (Süssw. F. Deut.).

T. tubifex (O. F. Müller) (Fig. 492). Reddish worms about 4 cm. long with about 60 segments; the forked setae in dorsal bundles in front of the clitellum have 1 to 3 middle teeth; ventral setae all forked: in mud in standing and running fresh water; often common, forming reddish patches on the mud where they are seen waving their hinder ends in the water; Europe.

2. CLITELLIO Savigny. Forked setae alone present; contractile hearts in segments 8 and 9; no blood capillaries in body wall; prostate glands diffuse: 1 species.

C. arenarius (O. F. Müller) (*C. irroratus* Verrill). Body very slender and reddish, up to 6 cm. long; setae sigmoid: Long Island Sound to Maine, often very common under rocks and stones near high-water mark on the seashore; Europe.

3. Bothrioneurum Stolc. Forked setae alone present; ventral setae of segment 11 modified for copulatory purposes: several species.

B. glaber Moore. Body pinkish or brown, 4 cm. long and .8 mm. wide; setae short and forked at the end: Vineyard Sound, under decaying vegetation and stones near high-water mark, especially where the water is brackish.

4. Limnodrilus Claparède. Forked setae alone present; contractile hearts in segment 8 and 9; blood capillaries penetrate the body wall; prostate gland large and massive, in segment 11: about 10 species, in fresh water.

L. claparedianus Ratzel. Length 4 to 7 cm.; segments 150: eastern states, in fresh water.

L. subsalsus Moore. Body red or brown in color and 4 cm. long; segments 120; setae deeply bifid, 4 to 6 being in each group before and 2 to 4 behind the clitellum: in brackish water at New Bedford, Mass.

Family 7. LUMBRICULIDAE.

Small worms usually red or brown in color, living in mud in fresh water; 2 pairs of dorsal and 2 of ventral setae in each segment; 2 pairs of sperm ducts, but with 1 pair of openings: 8 genera and about 15 species.

1. Trichodrilus Claparède (*Thinodrilus* Smith). Setae simple or forked at the end; dorsal blood vessel with paired contractile, blind appendages; male pores in segment 10: 3 species.

T. inconstans (Smith). Length 6 cm.; width 8 mm.; color reddish, anteriorly greenish; 5 pairs of small spermathecae: in mud or vegetation in fresh water.

Family 8. MEGASCOLICIDAE.

Usually terrestrial, sometimes aquatic oligochæts; setae curved, 8, 12, or more on a segment; male pores on segment 18 or 17; clitellum beginning on or before segment 16, not appearing excepting at certain times and without sharp boundaries: 56 genera and about 600 species, principally in the southern hemisphere and the tropical portions of the northern.

1. Diplocardia Garman. Setae paired, 8 on a segment, absent on segment 18; clitellum on segment 13 to 18: about 10 species, all American.

D. communis* Gar. Length 30 cm.; diameter 3 mm.; flesh-colored; dorsal vessel double; 3 pairs of spermathecae in segments 7 to 9: in the soil of the prairies (Illinois).

* See "On the Anatomy and Histology of a New Earthworm (*Diplocardia communis*)," by H. Garman, Bull. of Ill. St. Lab. of Nat. Hist., Vol. 3, p. 47, 1892.

D. riparia Smith. Length 25 cm.; diameter 3 mm.; color brown; dorsal vessel single; 2 pairs of spermathecae, in segment 8 and 9: in wet forest soil (Illinois).

Family 9. GEOSCOLECIDAE.

Aquatic or terrestrial, usually tropical oligochæts with 8 curved setae in a segment, paired or not; clitellum concave ventrally; male pores just before or in clitellum; gizzard in middle of œsophagus: 20 genera and about 90 species.

Sparganophilus Benham. Prostomium not marked off from peristomium; clitellum in segments 15 to 25; male pores on segment 19; 4 pairs of setae on a segment, a pair on each corner of the quadrangular cross section: in the mud of streams; 4 species.

S. eiseni Smith. Length 20 cm.; diameter 2.6 mm.; dorsal setae project laterally beyond the ventral; a pair of large glands open on segment 3; central and western states, in mud of springs.

S. tamesis Benham. Length 10 cm.; color red or blue; ventral setae project laterally beyond the dorsal: Philadelphia; England; on water plants.

Family 10. LUMBRICIDAE.

Earthworms. Terrestrial, occasionally aquatic, oligochæts with 4 pairs of setae to a segment; clitellum concave ventrally, not beginning before segment 18 or after segment 61; male genital pores on segment 15 (rarely on segments 11 to 14); 2 pairs of testes in segments 10 and 11 (rarely 1 pair); 1 pair of ovaries in segment 13; cocoons egg-shaped: 5 genera and over 100 species.

Key to the genera of *Lumbricidae* here described:

a_1 Peristomium completely divided dorsally by prostomium (Fig. 493). ..... 1. Lumbricus

a_2 Peristomium incompletely divided by prostomium (Fig. 494).

b_1 Gizzard occupies more than 1 segment; clitellum reaches at least through segment 32.

c_1 Clitellum begins mostly on segment 24 ..... 2. Eisenia

c_2 Clitellum begins mostly behind segment 24 ..... 3. Helodrilus

b_2 Gizzard occupies but 1 segment; clitellum reaches at most to segment 27 ..... 4. Eiseniella

1. Lumbricus L. Peristomium (buccal segment) completely divided by prostomium (Fig. 493); setae strictly paired; 3 pair vesiculae seminales present in segments 10 and 11 which fuse together in the middle line; 2 pairs of spermathecae, in segments 9 and 10; tail end flattened: 8 species, 3 American.

Key to the American species of *Lumbricus:*

a_1 Clitellum on segments 31 or 32 to 37.....L. TERRESTRIS
a_2 Clitellum on segments 26 or 27 to 32.....L. RUBELLUS
a_3 Clitellum on segments 28 to 33.....L. CASTANEUS

L. terrestris L. (Fig. 478). Length up to 30 cm., with about 180 segments; color purplish; clitellum on segments 31 or 32 to 37: in wet places; Europe and America.

L. rubellus Hoffmeister. Length up to 15 cm. with about 150 segments; color pink; clitellum on segments 26 or 27 to 32, usually nearly in center of body: in wet places; cosmopolitan.

L. castaneus (Savigny). Length up to 5 cm. with about 90 segments; color chestnut or violet brown, strongly iridescent; clitellum on segments 28 to 33: America and Europe.

2. **Eisenia** Malmgren (*Allolobophora* Eisen) (Fig. 494). Peristomium incompletely divided by prostomium; 3 or 4 pairs of vesiculae seminales which do not fuse together in the middle line; 2 or 3 pairs spermathecae in segments 8 to 11; tail end cylindrical: 9 species, 3 American.

Fig. 493

Fig. 494

Fig. 493 — Diagram showing completely divided peristomium (Süssw. F. Deut.). 1, prostomium; 2, peristomium. Fig. 494 —Diagram showing incompletely divided peristomium (Süssw. F. Deut.).

E. fœtida (Savigny). Length up to 9 cm. with about 100 segments; color pink with a dark ring on each segment; clitellum on segments 24, 25, or 26 to 32; setae strictly in pairs; 2 pairs spermathecae, in segments 9 and 10: the worm lives often in manure and has a disagreeable odor; cosmopolitan.

E. rosea (Sav.). Length up to 6 cm. with about 150 segments; color red; clitellum on segments 24, 25, or 26 to 32; 2 pairs of spermathecae in segments 10 and 11; setae strictly paired: in wet places; cosmopolitan.

3. **Helodrilus** Hoffmeister (*Allolobophora* Eisen). Peristomium incompletely divided by prostomium (Fig. 494); 2 to 4 pairs vesiculae seminales which do not fuse together in the middle line; tail end cylindrical: 54 species, 10 American.

H. caliginosus (Savigny). Length up to 17 cm. with about 250 narrow segments; color very variable, being gray, pink, yellowish, or bluish, but never purple; clitellum on segments 27 or 28 to 35; setae strictly paired; 4 pairs vesiculae seminales; 2 pairs spermathecae: in fields and gardens; cosmopolitan.

H. chloroticus (Sav.). Length up to 6 cm. with about 125 segments; color variable, but never purple; clitellum on segments 29 to 37;

setae in pairs, close together; 3 pairs of spermathecae in segments 9, 10, 11; 4 pairs vesiculae seminales: terrestrial; cosmopolitan.

H. palustris* (H. F. Moore). Length 7 cm.; segments 100; color red; clitellum on segments 23 to 28; 2 pairs vesiculae seminales; no spermathecae: Pennsylvania to North Carolina; in wet soil.

4. Eiseniella Michaelsen (*Allurus* Eisen; *Allolobophora* Eisen). Peristomium incompletely divided by prostomium (Fig. 494), clitellum beginning with the segment 23 or in front of it; male pores on segment 11 to 15; gizzard confined to segment 17; 4 pairs vesiculae seminales, which do not fuse in the middle line: 2 species.

E. tetrædra (Savigny). Color yellow, brown, or blackish; hinder and middle portions of body rectangular; length 5 cm.; thickness 4 mm.; segments 90; male pores on segment 13, female pores on segment 14; clitellum on segments 22 or 23 to 27: cosmopolitan; in wet soil.

Order 3. ECHIURIDA.†

Thick-bodied, cylindrical annelids in which the segmentation is wanting or indistinct in the adult. The animals are, however, born as typical trochophore larvae and at an early period of the metamorphosis have fifteen rudimentary somites. Parapodia and cephalic appendages are wanting. A pair of large setae is present on the ventral side near the forward end; in *Echiurus* two groups of setae are also present at the hinder end.

The formation of the head is peculiar. The prostomium is very much elongated and forms a long spatulate or trough-like structure in front of the mouth, which may be very elastic and forked at the end. The grooved ventral surface of the prostomium is ciliated and in it the minute animals which constitute the food of the worm are swept into the mouth. The prostomium is called the proboscis.

The alimentary canal is much longer than the body and terminates with the anus at the hinder end; joining the rectum is a pair of long cylindrical anal pouches which communicate with the body cavity and are modified nephridia. From one to three pair of typical nephridia are also present in the forward part of the body. The vascular system consists of a dorsal and a ventral longitudinal blood vessel, which join each other anteriorly, and no lateral vessels. The nervous system includes a ventral chord which is segmented in the early developmental stages but unsegmented in the adult. A distinct brain is wanting, but an

* See "On the Structure of Bimastus palustris, a New Oligochæte," by H. F. Moore, Jour. Morph., Vol. 10, p. 473, 1895.

† See "Thallasema mellita," by H. W. Conn, Stud. Biol. Lab., J. H. U., Vol. 3, 1884. "North American Echiurids," by C. B. Wilson, Biol. Bull., Vol. 1, p. 163, 1900.

œsophageal ring is present which is much elongated, as it extends from the front end of the prostomium to the ventral chord back of the mouth. Special sense organs are wanting but the prostomium acts as a feeler. The animals are unisexual, the gonad being unpaired but the ducts paired.

Fig. 495 *Echiurus pallasi* (Wilson). 1, proboscis 2, setae.

The *Echiurida* are marine worms which live in the sand and mud or between stones, usually near the shore. The order contains about 20 species and 5 genera, 3 genera and 5 species being known on the Atlantic and 1 species on the Pacific coast.

Key to the genera of *Echiurida* here described:

a_1 Preanal bristles present.....1. ECHIURUS
a_2 No preanal bristles.....2. THALASSEMA

1. ECHIURUS Cuvier. Preanal bristles and 2 ventral hooks present; body marked with rings bearing spines; 2 or 3 pairs of nephridia: 3 species.

E. pallasi Guérin (*E. chrysacanthophorus* Pourtalès) (Fig. 495). Proboscis spoon-shaped but cylindrical at base; about 22 body rings present; color gray, yellow, or orange; length 30 cm. or less; length of proboscis 6 cm.; width 6 cm.: North Atlantic (Casco Bay) and Alaska; Europe.

2. THALASSEMA Gaertner. Proboscis rather pointed at end; no preanal bristles but 2 ventral hooks present; 1 to 4 pairs of nephridia: 12 species.

T. melitta Conn (Fig. 496). Color dull red with 8 longitudinal bands; proboscis light yellow; length 25 mm., exclusive of proboscis, which is long and flexible: Beaufort, N. C., often in sand-dollar shells.

Fig. 496 *Thalassema melitta* (original) drawing by H. W. Conn).

CLASS 3. HIRUDINEA.*

Leeches (Fig. 501). Dorso-ventrally flattened, often brightly colored annelids, which are completely segmented internally and are marked externally with three or more rings to each somite. A large sucker is present at the hinder and a small one at the forward end by means of which the animal moves on hard surfaces. Parapodia, tentacles, and setae

* See Leeches of the U. S. Nat. Museum," by J. P. Moore, Proc. U. S. Nat. Mus., Vol. 21, p. 543, 1898. "The Hirudinea of Illinois," by J. P. Moore, Bull. Ill. St. Lab., Vol. 5, p. 479, 1901. "Notes on the Leeches of Nebraska," by H. B. Ward, Studies from the Zool. Lab. Neb., No. 51. "Hirudinea and Oligochæta Collected in the Great Lake Region," by J. P. Moore, Bull. U. S. Fish. Bur., Vol. 26, p. 155, 1905. "Die Süsswasserfauna Deutschlands, Hirudinea," by L. Johansson, 1909. "The Leeches of Minnesota," by J. P. Moore, Part III, Geog. and Geol. Sur. Minn., 1912.

are wanting. *Acanthobdella,* a Russian fresh-water leech, is an exception to this rule, having setae on the first five somites. Paired gills are present in a few genera. The head is not distinctly marked off from the trunk but the prostomium projects in front of the mouth, as in the *Oligochæta.* The body cavity differs in character from that in most other annelids in that it is filled secondarily with a vacuolated parenchyma; several tube-like spaces are, however, still left in it which are connected with the vascular system and contain blood.

The mouth is ventral or subterminal in position and opens into a pharynx which is provided with salivary glands and in turn leads into the œsophagus and the large crop; this organ has paired segmental pouches and passes back to the stomach, which may also be provided with paired pouches. The short intestine passes to the anus at the hinder end of the body above the sucker. The pharynx (Fig. 497) is provided with three serrated chitinous plates in the medicinal leech and its allies, by means of which the animal may draw blood from the body of its host. The *Rhynchobdellidae,* on the other hand, have no such plates but a proboscis which can be thrust out of the mouth and be made to pierce the skin of another animal. The main vascular system consists in general of four longitudinal blood vessels, a dorsal, a ventral, and two lateral. The excretory system consists of paired nephridia in the middle portion of the body (seventeen pairs in *Hirudo*), the inner ends opening into the sinuses representing the body cavity. The nervous system is like that of other annelids. The two longitudinal nerves are close together and several of the anterior ganglion pairs are fused together forming an infra-œsophageal ganglion. The special sense organs consist of a number of pairs of eyes (in *Hirudo* five) at the forward end of the body and sense buds which are most numerous at the forward end.

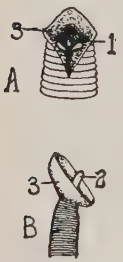

Fig. 497—A, anterior end of a medicinal leech; B, anterior end of a rhynchobdellid (Süssw.F.Deut.) 1, chitinous jaws; 2, extended proboscis; 3, oral sucker.

The leeches are hermaphroditic. A number of pairs of testes alternate usually with the segmental lateral pouches of the digestive tract and communicate with a pair of vasa deferentia which proceed to the male genital pore in the anterior part of the body, joining to form a penis at their anterior end. The female pore lies just behind the male; two ovaries are present which are joined by the oviducts with the vagina. Fertilization is effected by means of a spermatophore and the eggs are usually laid in a cocoon formed by a clitellum on the ninth, tenth, and eleventh somites. The young animal is born with the form of the parent.

Leeches are mostly aquatic animals which live in fresh water in all parts of the world; a few live in the sea and a few in moist earth. They are predacious animals, feeding on oligochæts, snails, and other small animals and are also at times external parasites, sucking the blood of aquatic vertebrates. The class contains two orders and about 150 species.

Key to the orders of *Hirudinea:*

a_1 Proboscis present and no jaws; blood colorless; somites rarely consisting of 5 rings each.....1. RHYNCHOBDELLIDA
a_2 No proboscis but usually 3 jaws present; blood red; somites usually consisting of 5 rings each.....2. GNATHOBDELLIDA

ORDER 1. RHYNCHOBDELLIDA.*

Leeches with a proboscis which can be thrust out of the mouth, and no jaws, and with colorless blood; segments consisting of 3 or more but rarely of 5 rings each: 2 families.

Key to the families of *Rhynchobdellida:*

a_1 Both suckers distinct from body.....1. ICHTHYOBDELLIDAE
a_2 Hinder sucker distinct, forward sucker more or less fused with body. 2. GLOSSIPHONIIDAE

FAMILY 1. ICHTHYOBDELLIDAE.

Leeches parasitic on fishes, tortoises, and some other animals; both suckers pedunculate; body elongate, narrow anteriorly, and broad posteriorly; body segments containing more than 3 rings each: 7 genera.

Key to the genera of *Ichthyobdellidae* here described:

a_1 No gills present.....1. PISCICOLA
a_2 Gills present.
b_1 Paired papilliform vesicles act as gills.....2. CYSTOBRANCHUS
b_2 Paired arborescent gills present.....3. BRANCHELLION

1. PISCICOLA Blainville. Body cylindrical, distinctly annulated with many (usually 14) rings to a somite; eyes distinct: many species.

P. rapax (Verrill) (Fig. 498). Body long and slender, dark olive in color with a row of rectangular white spots along each side; length 40 mm.; width 2 mm.: on the summer flounder.

Fig. 498 *Piscicola rapax* (Verrill).

P. funduli (Verr.). Body smooth, distinctly annulated, light green in color with fine dots of brown and green; length 18 mm.; 2 large and 2 small eyes: on *Fundulus pisculentus.*

* See "Some North American Freshwater Rhynchobdellida and Their Parasites," by W. E. Castle, Bull. Mus. Comp. Zool., Vol. 36, p. 17, 1900.

2. **Cystobranchus** Diesing. Gills present in form of paired papil liform vesicles along the sides of the body; body composed of 2 regions, a narrow anterior region of 11 somites and a broad posterior region; each segment contains 7 rings: 2 species.

C. vividus Verrill. Body with 11 pairs of vesicles, brownish or purplish in color with 3 irregular rows of white spots on the back; length 25 mm.; eyes 4: on *Fundulus pisculentus;* Long Island Sound; also in fresh water.

3. **Branchellion** Savigny. Gills present in form of paired aborescent appendages; body with a slender anterior neck: several species.

B. raveneli (Girard) (Fig. 499). Body with about 30 pairs of gills, dark brown or purple in color; length 6 cm.: on skates and rays.

Family 2. GLOSSIPHONIIDAE.

Fresh-water leeches in which the anterior sucker is fused with the body and the posterior sucker is distinct; each segment contains 3 rings; no cocoon is formed, the eggs and young being fixed to the mother's body: several genera.

Fig. 499

Fig. 500

Fig. 499—*Branchellion raveneli* (Verrill). Fig. 500—*Glossiphonia complanata*—anterior end showing eyes (Süssw. F. Deut.).

1. **Glossiphonia** Johnson (*Clepsine* Savigny). Body wide, attenuated forward, often brightly colored; animal cannot swim but rolls up when alarmed: numerous species; in fresh water.

G. parasitica (Say) (*Clepsine plana* Whitman). Body broad and flat, with a smooth surface; color variegated, being greenish or yellowish, with longitudinal rows of spots; lower surface longitudinally striped; 2 eyes; length 6 cm.; width 2.6 cm.: the most abundant American species; on turtles or under stones.

G. complanata (L.) (Fig. 500). Body 30 mm. long and 10 mm. wide, very flat; color greenish, spotted with yellow; eyes 6, in 3 pairs: often common under stones in running water; very active; Europe.

G. fusca Gastle (*G. lineata* Verrill). Body 12 mm. long, flat and broad, with 12 longitudinal brown stripes; 2 large eyes: in cold streams.

G. elegans (Verr.) (Fig. 501). Body elliptical, 18 mm. long and 7 mm. wide, brownish in color; head colorless; 6 eyes: abundant in shallow waters, often with *G. stagnalis;* sluggish in its movements.

G. rugosa (Verr.). Body rough and papillose; color variegated, spotted irregularly with yellow and green; 2 eyes; length 5 cm.: abundant under stones in running water.

Fig. 502 *Glossiphonia stagnalis* (Süssw. F. Deut.).

G. stagnalis (L.) (Fig. 502). Body small, rather elongate, grayish or pinkish in color, and 25 mm. long by 2 mm. wide when extended; 10 mm. long at rest; annulation distinct; 2 eyes; between rings 12 and 13 is a conspicuous brown, cuticular plate; crop with but one pair of pouches: in ponds and sluggish streams, where it feeds on small snails; very common; Europe; very active in its movements.

G. heteroclita (L.) (Fig. 503). Body transparent, yellowish or brownish in color, about 10 mm. long and 3 mm. wide, and with indistinct rings; 6 eyes arranged in pairs at the corners of a triangle: in ponds and sluggish streams; Europe.

Fig. 503 *Glossiphonia heteroclita* (Süssw. F. Deut.).

2. Hemiclepsis Vejdovsky. Anterior sucker pedunculate; body wide and flat: several species.

B. carinata Verrill. Body 35 mm. long, rather slender; color greenish with longitudinal stripes; eyes 2, conspicuous: common in streams, sometimes attached to frogs or toads.

Fig. 501—*Glossiphonia elegans*—diagram showing the digestive and genital tracts, seen from the dorsal surface, the somites being numbered on the left and the rings on the right side (Castle). an., anus; br., brain; cr., crop; in., intestine; ov., ovary; pr., proboscis; p.s., posterior sucker; sl., salivary glands; st., stomach; t., testis; ♂, male genital pore; ♀, female genital pore.

Order 2. GNATHOBDELLIDA.

Fresh-water and terrestrial leeches without a proboscis and usually with 3 jaws (Fig. 497, A); blood red: 2 families.

Key to the families of *Gnathobdellida:*

a_1 Three toothed jaws present.....1. Hirudinidae
a_2 Three unarmed muscular ridges present in place of the jaws.
2. Herpobdellidae

Family 1. HIRUDINIDAE.

Leeches with 3 toothed jaws; segment contains 5 rings; 5 pairs of eyes: several genera.

1. Hirudo L. Elongate, flattened leeches with about 95 annulations; margin of body serrate; crop with about 10 pairs of lateral pockets; teeth very numerous, over 100 in number; body contracts and does not roll up: numerous species.

Fig. 504 Fig. 505

Fig. 504—*Herpobdella punctata* (Moore). Fig. 505—*Herpobdella fervida* (Moore).

H. medicinalis L. The medicinal leech. Body yellowish-brown, 10 to 20 cm. long: an European animal which has been introduced into some ponds and streams in the eastern United States; used for bloodletting.

2. Hæmopis Savigny. Body rather thick, with smooth margins; crop with 1 pair of cæca but without lateral pockets; teeth few, about 20; 5 pairs of eyes.

H. marmoratis (Say). The horseleech. Body 10 cm. long or more, 15 mm. wide, smooth, and very soft; color variegated, being blackish or brownish, blotched with irregular spots: in the mud at the side of pools and streams and also occasionally on the land; will occasionally suck blood but usually eats worms, snails, etc.

H. grandis (Verrill). Body 20 cm. long or more, specimens 45 cm. having been found; color yellow, mottled with black; the largest American leech: New England, the Great Lakes, and westward.

3. Macrobdella Verrill. Body strongly annulated, broad and flattened, and tapering but little; about 65 teeth on each jaw; male orifice between segments 26 and 27 and the female orifice between segments 31 and 32: 3 species.

M. decora (Say). Body up to 30 cm. long and 25 mm. wide, brown or olive green in color, with a median row of about 20 red spots and a row of black spots near each margin; lower surface reddish: very common in fresh water, a fierce blood sucker, attacking men, cattle, fish, frogs, etc., but also eating other animals.

Family 2. HERPOBDELLIDAE.

Body subcylindrical, elongate with 3 unarmed muscular ridges in place of jaws; crop without lateral pockets: several genera.

1. **Herpobdella** Blainville (*Nephelis* Savigny). Body long and narrow and with smooth margin; segments contain 5 rings each; genital orifices separated by 2 or 3 rings: many species; on plants and on the under side of stones in streams.

H. punctata (Leidy) (Fig. 504). Body up to 10 cm. long and 1 cm. wide; color brownish-black with 4 longitudinal rows of irregular black spots; 3 pairs of eyes: common in streams and pools.

H. (*Dina* Blanchard) **fervida** (Verrill) (Fig. 505). Body up to 5 cm. long, variegated pale red in color; 3 or 4 pairs of eyes: abundant in the Great Lakes region.

Class 4. MYZOSTOMIDA.*

These animals are small disc-shaped parasites of crinoids, ophiurans, and starfishes, on the bodies of which they live either in cysts or free. The body is oval in outline, much flattened, and externally unsegmented. It possesses, however, five pairs of parapodia, each of which is stiffened by two setae, and four pairs of latero-ventral sucker-like organs which are probably sense organs. The edge of the body is serrate in some species; in others ten pairs of short cirri extend from it. A distinct head is not present (Fig. 506).

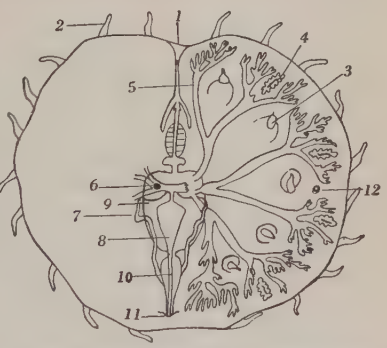

Fig. 506—Diagram of a myzostomid (von Stummer). 1, mouth; 2, cirrus; 3, parapodium; 4, lateral sense organ; 5, intestinal branches; 6, ovary; 7, nephridium; 8, uterus; 9, stomach; 10, cloaca; 11, anus; 12, male genital pore.

The body cavity is obliterated by the growth of a vascular parenchyma throughout it. The mouth is ventral in position and near the anterior end of the body; it opens into the pharynx, which forms a proboscis. The intestine is straight and sends out a number of long branches on each side. The anus is near the hinder end of the body. Special vascular and respiratory organs are wanting; nephridia are present. The nervous system is highly specialized. It consists of two

* See "Verzeichniss der von den U. S. Coast Survey Steamers Hassler und Blake, von 1867-1879, gesammelten Myzostomideen," by L. von Graff, Bull. Mus. Comp. Zool., Vol. 11, p. 125, 1883. "The Sexual Phases of Myzostoma," by W. M. Wheeler, Mitt. aus d. Zool. St. zu Neap., Vol. 12, p. 227, 1896. "New Marine Worms of the Genus Myzostoma," by J. F. McClendon, Proc. U. S. Nat. Mus., Vol. 32, p. 63, 1907.

œsophageal nerve rings and a large ventral nerve mass which is composed of about six fused pairs of ganglia and sends off numerous nerves. No special sense organs are present. The animals are hermaphrodite. The testes are paired, branched organs which are joined on each side by two vasa deferentia with a lateral sperm sac; this opens to the outside by a marginal pore near the middle of the body. Two ovaries are present; the ova are collected in a median uterus which communicates with the rectum.

The class includes over 70 species and 2 genera.

Myzostoma F. S. Leuckart. With the characters of the class: numerous species.

M. glabrum F. S. Leuck. Body nearly circular, 4 mm. long, with 10 pairs minute protuberances; parapodia short; cloaca dorsal: Europe, on *Antedon rosacea,* attached to the oral plates.

M. cubanum McClendon. Diameter 1.7 mm.; thickness .08 mm.; dorsal surface flat, with 10 pairs of short conical cirri; ventral surface convex; parapodia prominent; suckers absent: West Indies, from crinoids off Havana.

PHYLUM V.

ARTHROPODA. (Crustaceans, Arachnids, Myriapods, and Insects.)

Animals which are externally segmented and have segmented extremities (Fig. 542, A).

External Structure.—The segmentation of arthropods is heteronomous, the somites or body segments being unequal in size, and in most cases the body is made up of three divisions, the head, the thorax, and the abdomen. Fusion occurs very frequently between contiguous somites so that their boundaries are obliterated: the somites of the head are always thus fused. The appendages or extremities are elongated, segmented projections of the ventral body wall, there being typically a single pair on each somite except on the terminal one. In many cases where the segmentation has disappeared secondarily the number of pairs of appendages gives a clue to the number of somites originally present.

The appendages are primarily locomotory and sensory organs, but we find them performing many other functions. The first pair forms the antennae or feelers, where these are present, and their function is usually purely sensory. One or more pairs form the jaws, which have thus a right and left position. The appendages of the middle and hinder part of the body usually preserve their locomotory function and form the walking or swimming legs. These, however, often serve also other purposes, as for respiration and the transportation of eggs or young, or as spinnerets in spiders, and as stings, anal feelers, and ovipositors among the insects.

The following scheme taken from Korschelt & Heider's *Textbook of Embryology* illustrates the homologies of the anterior pairs of appendages in the principal groups of *Arthropoda:*

CRUSTACEA	ARACHNIDA	INSECTA
Antennae 1.		Antennae.
Antennae 2.	Mandibles.	
Mandibles.	Pedipalps.	Mandibles.
Maxillae 1.	Legs 1.	Maxillae.
Maxillae 2.	Legs 2.	Labium.
Thoracic appendages 1.	Legs 3.	Legs 1.
Thoracic appendages 2.	Legs 4.	Legs 2.
Thoracic appendages 3.		Legs 3.

The largest group of arthropods, the insects, is distinguished by the possession of wings, two pairs of which are typically present, arising as projections from the dorsal wall of the thorax.

The principal organs of special sense are the eyes, the tactile hairs, and the auditory or balancing organs. The tactile hairs are usually distributed over the body, but are probably most sensitive on the antennae and the palps, where they are organs of touch, hearing, taste, or smell. The eyes are of two kinds, simple and compound. A simple eye or ocellus is a minute structure formed by a modification of the integument and consisting of a convex retina and a lens. A compound eye is a much larger and more complex structure and consists of a large number of distinct elements called ommatidia. Each of these is a separate light-perceiving body, and the sum of the images of all the ommatidia of a compound eye forms the picture the animal sees. This is called mosaic vision and characterizes crustaceans and insects alone among animals. A pair of lithocysts, or so-called auditory organs, are present in certain crustaceans; they are organs of equilibration. A few species of insects have genuine auditory organs.

The integument of arthropods is composed of a shell-like cuticula which forms the entire outer surface, and a layer of glandular cells called the hypodermis which lies beneath the cuticula and secretes it. The cuticula is rendered tough and thick by the presence of chitin and sometimes of calcium carbonate and forms a very efficient outer covering. During the period of growth an arthropod sheds its cuticula periodically.

Arthropods are often highly colored, some of them being among the brightest of animals: many are protectively colored and many crustaceans are transparent, being almost invisible in the water in which they live. Sexual dimorphism is very common, the males being distinguished from the females by size, color, or other external markings.

Internal Structure.—The digestive tract extends from the mouth to the anus and is made up of foregut, midgut, and hindgut, which, however, in all arthropods have undergone a large degree of specialization. Salivary glands are generally present in the terrestrial arthropods but are absent in the aquatic ones. Other digestive glands are wanting in insects, but in crustaceans and arachnids a voluminous liver is often present. The excretory organs or kidneys are present in the form of one or more pairs of tubular glands.

The circulatory system is not highly specialized. A blood fluid is always present which circulates among the organs in the extensive body cavity. In many small crustaceans no heart or other vessels are present, but the circulation is maintained by the movements of the intestine or of

the whole body. In most arthropods, however, a heart, usually tubular in shape, is present in the dorsal part of the body cavity, the beating of which keeps the blood in circulation. In no arthropods, however, is there a closed vascular system, as the blood, even in the highest, passes from the tissues to the respiratory organs through open spaces of the body cavity. In most arthropods respiratory organs in the form of projections from the legs or the sides of the body are present. In the crustaceans these projections extend into the water and form the gills, while in the air-breathing forms the projections extend into the body cavity and become the so-called lungs of the arachnids or the tubular tracheae which carry respiratory air directly to the blood. The muscular and nervous systems of arthropods are highly developed. The muscles are all striated and are probably the most energetic among animals.

The main nervous system, like that of annelids, consists of a number of pairs of segmentally arranged ganglia and nerves connecting them. The anterior pair constitutes the brain and is situated in the dorsal portion of the head; from it nerves go to the eyes and the antennae. The remaining parts are ventrally situated, one pair being typically in each somite. In most arthropods, however, fusion has occurred among the ganglia so there are fewer pairs of them than of somites. This fusion has gone so far in some of the highest arthropods that all the ventral ganglia have come to form a single mass. In all arthropods the brain is distinct and is joined with the ventral ganglia by a pair of connecting nerves, one of which passes on each side of the œsophagus.

With a few exceptions arthropods are unisexual, the hermaphroditic forms being a few parasitic or sessile crustaceans and a few arachnids. The gonads are usually paired, tubular glands which open to the outside by a pair of openings in crustaceans and by a single median abdominal opening in most other arthropods. Parthenogenesis occurs among certain crustaceans and insects, and pædogenesis occurs as a rare phenomenon among the latter.

Arthropods are generally characterized by the care they take of their eggs and young. Many of them carry their eggs until they hatch, and often the young animals are also carried. Among insects a family life of remarkable complexity characterizes many species, which often leads to the formation of colonies characterized by a division of labor among their individual members, as in the case of the bees, termites, and many others.

Distribution.—Arthropods constitute the largest phylum of animals, numbering about 400,000 known species, or four-fifths of all known species of animals. They form also one of the most widely distributed groups, being found in all parts of the sea and land. The crustaceans

are almost exclusively aquatic and the arachnids and tracheates almost exclusively terrestrial and aerial animals.

History.—Linnæus gave the name *Insecta* to all the animals which are now included under the *Arthropoda,* the crustaceans, spiders, and myriapods being *Insecta aptera.* Cuvier in 1800 created the *Crustacea* as an independent class, and Lamarck in 1801 performed the same service for the *Arachnida,* restricting the term *Insecta* to the *Hexapoda* and the *Myriapoda.* The last-named group was created in 1796 by Latreille. All these animals were joined by Cuvier with the *Annelida* to form the *Articulata,* but in 1845 von Siebold separated the *Annelida* from the others, making a class of them under the *Vermes,* and formed an independent group of the *Crustacea, Arachnida,* and *Insecta* to which he gave the name *Arthropoda.*

The phylum contains 3 classes.

Key to the classes of *Arthropoda:*

a_1 Aquatic arthropods (with a few exceptions) having gills and 2 pairs of antennae .....1. CRUSTACEA
a_2 Air-breathing arthropods (with a few exceptions).
b_1 Antennae absent.....2. ARACHNOIDEA
b_2 One pair of antennae present.....3. TRACHEATA

CLASS 1. CRUSTACEA.*

Aquatic arthropods which breathe by means of gills and have 2 pairs of antennae and biramose appendages (Fig. 542).

External Structure.—An elongated body with distinct segmentation, in which the primary division into head, thorax, and abdomen is evident, characterizes most crustaceans. A tendency is however present in all the groups towards a fusion of the somites and a shortening of the body. Those forming the head are always thus fused and are besides often joined with some or all of the thoracic somites, forming thus a body division called the cephalothorax, which in many crustaceans is wholly or partly covered by a bivalve shield called the carapace.

The appendages are fitted primarily for locomotion and respiration in the water and are typically biramose, each consisting of a basal piece, the protopodite, and two segmented, terminal pieces, an outer one, the exopodite (Fig. 516,16), and an inner one, the endopodite (Fig. 516,17). Although this is the primitive condition of the appendage, the performance of special functions has in many cases brought about a modification of it and often a loss of some of its parts.

* See "Crustacea," by A. Gerstaecker and A. E. Ortmann. Bronn's "Klass. u. Ord. d. Thierreichs," Bd. 5, Abt. 1 and 11, 1866-1901. "Crustacea," by J. S. Kingsley, Standard Natural Hist., Vol. 2, 1888. "List of the Crustacea," by Mary J. Rathbun, Fauna of New England in Occasional Papers of the Boston Soc. of Nat. Hist., VII, 1905.

Five pairs of appendages are present in the head, the first antennae, second antennae, mandibles, first maxillae, and second maxillae. Of these, the first pair of antennae (antennules) differs from all the other appendages of the body in not being typically biramose; they are not, however, necessarily simple, but the distal portion of the appendage is frequently split into two, three, or more branches, called flagella (Fig. 614, 1). The mandibles are short, stout appendages, fitted for biting, and may bear a sensory palp which is the modified endopodite, the exopodite being wanting. The two pairs of maxillae are usually delicate structures whose function is probably chiefly sensory.

The number of thoracic appendages varies greatly among crustaceans. The smallest number of pairs (2) is found among ostracods and the largest number (60) among the *Apodidae.* The abdominal appendages are wanting in the *Entomostraca* and in the youngest larval forms of most *Malacostraca.* In adults of the latter group, however, these are present on all the abdominal segments except the last one (telson).

The cuticula of crustaceans is shed periodically. In the smaller species it is very delicate and the animal is often quite transparent. In the large *Malacostraca* it contains calcium carbonate as well as chitin and is very hard and thick: it is such animals which have given the group the name *Crustacea.*

Internal Structure (Fig. 623).—The digestive tract is in most crustaceans a straight tube going from the ventrally located mouth to the anus at the hinder end of the body. Tubular livers, often very voluminous, are present in most forms; salivary glands are absent. The excretory organs consist of a pair of tubular glands, the kidneys, which open to the outside in the neighborhood of the mouth. The respiratory organs are lacking in some of the small crustaceans, the outer surface of the body performing this function. In most of them, however, gills are present, as projections of the thoracic or abdominal appendages or of the sides of the body.

With the exception of most of the *Cirripedia,* which are all either sessile or parasitic, all crustaceans are unisexual. Among the *Phyllopoda* and *Ostracoda* parthenogenesis is common. In the lower crustaceans the animal usually leaves the egg as a nauplius larva, a minute animal with three pairs of appendages, of which the first pair is uniramose and the second and third pairs are biramose. With a few exceptions (*Peneus, Lucifer*) all the higher crustaceans pass through the nauplius stage while still in the egg and are born in some later stage of development. Many of them, as the crayfish, have the form of the adult when born, the entire metamorphosis having been completed in the egg.

Habits and Distribution.—The sowbugs, land crabs, and a few other

forms live on the land, but all others are aquatic animals. The majority of these live in the sea, the *Phyllopoda* being the only order which is better represented in fresh than in salt water. Crustaceans feed largely on decaying animal and plant substances. Many are parasitic, especially among the *Copepoda, Cirripedia,* and *Isopoda.* The barnacles are the only sessile crustaceans.

History.—Crabs and other decapods have been known and used for food from time immemorial. They were first described by Aristotle who calls them *Malacostraca* or soft-shelled animals in contradistinction to the hard-shelled mollusks. Linnæus placed them among the *Insecta aptera.* The lower crustaceans were seen by the earlier microscopists, but very little studied or understood until the time of O. F. Müller, who in 1785 brought together a large number and called them *Entomostraca,* or insect-like crustaceans. Cuvier, Latreille, and Lamarck in the first years of the new century introduced the term *Crustacea* to include all crustaceans, although the term had already been used as a synonym of *Malacostraca.* The creation of the various orders of crustaceans is largely due to Latreille, who introduced the names *Branchiopoda, Isopoda, Amphipoda, Decopoda,* and *Phyllopoda.* Milne-Edwards formed the order *Copepoda,* and Burmeister introduced the terms *Arthrostraca* and *Thoracostraca.*

American crustaceans have attracted many able investigations from the time of Thomas Say in the first quarter of the last century to the present time. In 1852 appeared the *Crustacea of the Wilkes Expedition,* by James Dwight Dana, which was one of the most important zoological works of the day. This and the works of Say, Stimpson, S. I. Smith, and others form the groundwork of our present knowledge of American forms.

The class contains about 16,000 species, grouped in 2 subclasses.

Key to the subclasses of *Crustacea:*

a_1 Small, often minute crustaceans without abdominal appendages.
1. ENTOMOSTRACA

a_2 Larger crustaceans usually with abdominal appendages...2. MALACOSTRACA

SUBCLASS 1. ENTOMOSTRACA.

Small crustaceans, the majority of which are under a centimeter in length; somites variable in number; head, thorax, and abdomen usually distinctly marked, but in many the head and one or more thoracic somites are fused together, forming a cephalothorax; body either elongate with distinct segmentation or much shortened and enclosed in a chitinous shell called the carapace; parasitism has produced great changes in the form of many entomostraceans so that all semblance of the crustacean form is often lost; appendages confined to the head and the thorax, 5 pairs being

cephalic and the thoracic appendages varying in number from 2 pairs to 60: 4 orders with about 4,800 species.

Key to the orders of *Entomostraca:*

a_1 Free swimming or parasitic on fish (rarely on other animals).
  b_1 Thoracic appendages flattened and leaf-like; body either elongate and segmented or short and more or less covered with a carapace. 1. PHYLLOPODA
  b_2 Body either elongate and segmented with cylindrical thoracic appendages, or greatly modified when the animals are parasites.....2. COPEPODA
  b_3 Body short and unsegmented and entirely enclosed in a bivalve carapace .....3. OSTRACODA
a_2 Body sessile and enclosed in a calcareous shell (barnacles) or parasitic on decapods or mollusks.....4. CIRRIPEDIA

ORDER 1. PHYLLOPODA.*

Thoracic appendages flat and leaf-like, as the name indicates, being organs of respiration; body either long and vermiform and composed of numerous segments or short and compact and unsegmented; carapace usually present; parthenogenesis common, the usual eggs being relatively small and thin-shelled and called summer eggs; at the approach of a period of drought or cold males are born from the parthenogenetic eggs which fertilize the females, and the eggs which these then lay are large and thick-shelled and called resting or winter eggs, and are capable of enduring the winter's cold or the summer's drought, if need be: 2 suborders and more than 600 species, most of them being fresh-water animals, living in pools, lakes, and streams containing the minute algae which form their principal food.

Key to the suborders of *Phyllopoda:*

a_1 Body elongated and distinctly segmented.....1. BRANCHIOPODA
a_2 Body short with indistinct segmentation or without any, and usually with a bivalved carapace.....2. CLADOCERA

SUBORDER 1. BRANCHIOPODA.†

Elongated phyllopods with numerous distinctly marked segments, and either with or without a carapace; the young born as nauplii: several families and over 100 species, which, with a few exceptions, live in fresh water.

Key to the families of *Branchiopoda* here described:

a_1 Carapace absent.....1. BRANCHIPODIDAE
a_2 Carapace present.
  b_1 Carapace flattened dorsoventrally and arched.....2. APODIDAE
  b_2 Carapace compressed laterally.....3. LIMNADIIDAE

* See "Die Süsswasserfauna Deutschlands," Heft 10, 1909.

† See "Phyllopod Crustacea of North America," by A. S. Packard, 12th Ann. Rep. U. S. Geol. Sur. of the Ter., 1878 (1883), pt. 11, p. 294.

Family 1. BRANCHIPODIDAE.

Body elongate, being composed of many segments and without carapace; head distinctly set off; first antennae filiform; second antennae of male used for clasping the female, being very large and composed of 2 elongated segments and with or without extra frontal appendages between them; thoracic segments and appendages mostly 11; abdominal segments 8 or 9 in number; 2 stalked eyes present; a pair of egg sacs extend from the last thoracic segment of female: 8 genera; the animals live in fresh and salt pools and swim on their backs.

Key to the genera of *Branchipodidae* here described:

a_1 Frontal appendages present.
  b_1 Frontal appendages simple in form.....1. Branchipus
  b_2 Frontal appendages branched.....2. Chirocephalus
a_2 Frontal appendages absent.
  b_1 Abdomen with 8 segments.....3. Artemia
  b_2 Abdomen with 9 segments.....4. Branchinecta

1. Branchipus Schaeffer. Beween the second antennae of male are 2 unbranched frontal appendages; abdomen consisting of 9 segments

Fig. 507

Fig. 508

Fig. 507—*Branchipus vernalis*—male (Packard). 1, first antenna; 2, second antenna; 3, frontal appendage. Fig. 508—*Chirocephalus holmani*—front view of head of male (Packard). 1, eye; 2, first antenna; 3, second antenna; 4, frontal appendage.

and 2 long caudal projections which have setose margins: 2 American species.

B. vernalis Verrill. The fairy shrimp (Fig. 507). Body semitransparent and pinkish in color; length 23 mm.; frontal appendages broad and flat: eastern North America, in fresh-water pools during the spring, autumn, and winter, passing the summer as resting eggs; often common, but sporadic.

2. Chirocephalus Prévost. Between the second antennae of male 2 very long, branched, and coiled frontal appendages; abdomen consisting of 9 segments and with 2 long, broad caudal projections with setose edges: 1 American species.

C. holmani Ryder (Fig. 508). Body slender, 15 mm. long: eastern North America (Philadelphia, Long Island).

3. Artemia Leach. No frontal appendages present; second joint of second antennae flat and triangular; abdomen of 8 segments and with 2 very short caudal projections; egg sac short: several species, all in salt pools and lakes; 2 American species.

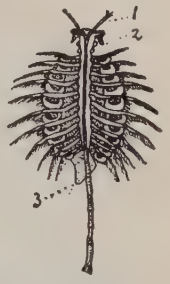

Fig. 509
Artemia gracilis (Packard).
1, first antenna
2, second antenna
3, ovisacs

A. gracilis Verrill (Fig. 509). Body semitransparent, pink or green in color, 10 mm. long: eastern and central North America, as far west as Great Salt Lake.

A. franciscana Kellogg. Body translucent whitish or dull brick red in color and slender; length 13 mm.; caudal appendages with setose edges: California.

4. Branchinecta* Verrill. No frontal appendages between second antennae, the second joint of which is simple and slender; abdomen of 9 segments; egg sac long and slender: 3 species, in the western states.

Fig. 510
Branchinecta coloradensis—front view of head of male (Shantz).
1, first antenna
2, second antenna

B. coloradensis Packard (Fig. 510). Length 18 mm.; second antennae large, and broad and bent in, and not serrate: very common in Colorado.

Family 2. APODIDAE.

Body elongate and composed of many segments, and with an oval, low-arched carapace covering the head and thorax; eyes sessile; first antennae short and filiform with 2 or 3 flagella; second antennae minute or wanting in the adult; 40 to 60 pairs of broad feet, the first pair ending with 3 long, slender branches, the eleventh pair forming egg capsules in the female; 2 long caudal bristles; larva a nauplius: 2 genera; in fresh water.

Fig. 511
Apus lucasanus (Packard).

Apus Schaeffer (*Triops* Schrank). With the characters of the family: about 4 American species, all in the western states.

A. lucasanus Packard (Fig. 511). Telson with 3 central spines; length, with caudal bristles, 41 mm.: western America, abundant in Kansas.

Family 3. LIMNADIIDAE.

Body elongate and entirely enclosed in an oval laterally compressed carapace, which gives the animal the appearance of a bivalve mollusk;

* See "Notes on the North Am. Species of Branchinecta," etc., by H. L. Shantz, Biol. Bull., Vol. 9, p. 249, 1900.

eyes sessile and close together; first antennae minute, second large, with 2 terminal branches; 18 to 28 pairs of broad feet, the first or the first and second pairs being prehensile in the male: in fresh water, differing from the *Cladocera* and *Ostracoda* in being much larger and in having distinct segmentation and more appendages and an abdomen which is not bent under the thorax; about 5 genera.

Key to the genera of *Limnadiidae* here described:

a_1 Lines of growth on shell; 24 pairs of feet.....1. CYZICUS
a_2 No lines of growth; 10 to 12 pairs of feet.....2. LIMNETIS

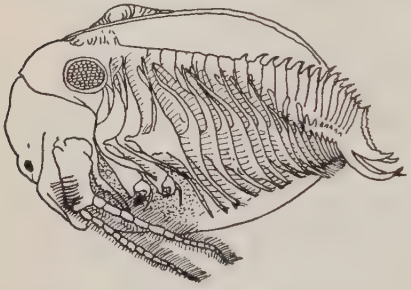

Fig. 512—*Cyzicus morsei* (Packard).

1. CYZICUS Audouin (*Estheria* Rüppell). Shell oval and opaque, amber-colored; body rather thick; head with a long narrow rostrum; about 24 pairs of flat feet, the first two pairs being prehensile in the male: numerous species, about 8 in America, all in the West.

C. morsei (Packard) (Fig. 512). Shell 12 mm. long, 8 mm. high, and 6 mm. across; the two branches of second antennae with 17 and 16 joints each: widely distributed throughout the central and western parts of the country.

2. LIMNETIS Lovén. Shell oval or spherical, with no lines of growth; head with a large rostrum; 11 or 12 pairs of feet, the first pair being prehensile in the male; eggs carried in a dorsal brood chamber: 4 species in America.

Fig. 513—*Limnetis gouldi* (Packard).

L. gouldi Baird (Fig. 513). Body rather thick; second antennae with 16 segments in each branch; length of shell 3 mm.; breadth 2.5 mm.; color pink; eyes black: eastern and central America, westward to the Mississippi.

SUBORDER 2. CLADOCERA.*

Water fleas. Body usually short and compact, without segmentation, and enclosed in a bivalve carapace; 4 to 6 pairs of thoracic appendages; first pair of antennae often minute, second pair very large,

* See "Notes on Cladocera," by E. A. Birge, Trans. Wis. Acad., Vol. 4, 1878. "List of Crustacea Cladocera from Madison, Wis.," by same, ditto, Vol. 8, 1891. "Notes on Cladocera," by same, ditto, Vol. 9, 1892. "Synopsis of the Entomostraca of Minnesota," etc., by C. L. Herrick and C. H. Turner, Second Rep. of State Zool., 1895. "The Cladocera of Nebraska," by Charles Fordyce, Stud. from the Zool. Lab. of the Univ. of Neb., No. 42, 1901.

with the two branches (exopodite and endopodite) prominent, and used for swimming; abdomen small and usually bent under the thorax; 2 large compound eyes which in many species unite to form a single median eye; a large dorsal brood sac in the female in which the eggs develop, the young animals being born with the form of the parent; the winter eggs are often provided with an extra shell called the ephippium, consisting of 2 chitinous plates, like watch crystals, whose edges fit together, one, two, or more eggs being in a single ephippium: about 8 families and several hundred species, most of which live in fresh water.

Key to the families of *Cladocera* here described:

a_1 Carapace enclosing the entire body.
  b_1 One branch of second antennae with 2 segments, the other with 3. 1. SIDIDAE
  b_2 One branch of second antennae with 3 segments, the other with 4.
    c_1 First antennae minute ..... 2. DAPHNIDAE
    c_2 First antennae long and beak-like ..... 3. BOSMINIDAE
  b_3 Both branches of second antenna with 3 segments ..... 4. LYNCEIDAE
a_2 Carapace not enclosing the legs and the abdomen.
  b_1 Abdomen curved and rudimentary; 4 pairs of legs; fresh and salt water ..... 5. POLYPHEMIDAE
  b_2 Abdomen straight and very large; 6 pairs of legs ..... 6. LEPTODORIDAE

FAMILY 1. SIDIDAE.

Head large and separated from the body by a depression and usually with a beak; first antennae one-jointed, but long in the male, with a long terminal flagellum; second antennae very long, the two branches having 2 and 3 segments respectively; 6 pairs of legs; heart elongate and intestine straight, without liver sacs: several genera.

Key to the genera of *Sididae* here described:

a_1 Dorsal branch of second antennae three-jointed ..... 1. SIDA
a_2 Dorsal branch of second antennae two-jointed.
  b_1 First joint of second antennae with a long side branch ..... 2. LATONA
  b_2 No such side branch ..... 3. DAPHNELLA

1. SIDA Straus-Dürkheim. Ventral branch of second antennae with 2 segments; dorsal branch with 3 segments; beak distinct: several species.

S. crystallina (O. F. Müller) (Fig. 514). Shell elongate with rounded ends; first antennae in male long, short in females; body colorless, sometimes with brown, red, and blue spots; length 2 mm.: in clear lakes; often widely distributed; often common; Europe.

Fig. 514—*Sida crystallina* (Süssw. F. Deut.). 1, second antenna; 2, first antenna; 3, abdomen; 4, brood sac.

2. LATONA Straus-Dürkheim. Ventral branch of second antennae with 3 segments, dorsal branch with 2 segments, the first segment having a long side branch: 1 species.

L. setifera (O. F. Müller). Body and appendages very setose; color yellowish, often with spots; length 3 mm.: among weeds in clear lakes; widely distributed; Europe.

Fig. 515 *Daphnella brachyura* (Süssw. F. Deut.). 1, second antenna 2, first antenna

3. **Daphnella** Baird. Ventral branch of second antennae with 3 segments; dorsal branch 2 segments; beak absent; no teeth on the abdomen; first antennae short in female: several species.

D. brachyura (Liévin) (Fig. 515). Length .7 mm.: in clear water; widely distributed; Europe.

Family 2. DAPHNIDAE.

Body oval; head rounded, usually with a short beak; first antennae usually minute, consisting of a single segment; the 2 branches of the second antennae consisting of 3 and 4 segments respectively; 5 pairs of legs, the last pair separated from that next to it; intestine not coiled and with a pair of liver sacs: about 12 genera.

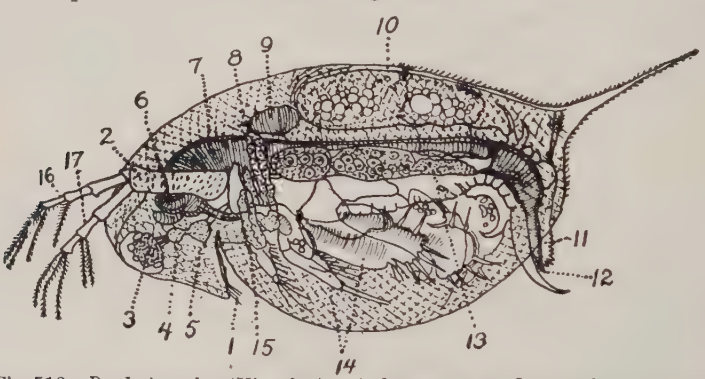

Fig. 516—*Daphnia pulex* (Kingsley). 1, first antenna; 2, second antenna; 3, eye; 4, optic ganglion; 5, brain; 6, liver sac; 7, intestine; 8, kidney; 9, heart; 10, brood sac with two eggs; 11, abdomen; 12, anus; 13, ovary; 14, legs; 15, mouth; 16, exopodite; 17, endopodite.

Key to the genera of *Daphnidae* here described:

a_1 Head terminating ventrally in a beak.
  b_1 Head not separated from body by a dorsal notch; shell with a caudal spine at the upper posterior angle.....1. Daphnia
  b_2 Such a notch present.
    c_1 Shell abruptly truncated behind, with a short spine at the lower posterior angle.....2. Scapholeberis
    c_2 Shell rounded below, with a blunt spine above.....3. Simocephalus
a_2 No beak, or a rudimentary one, present.
  b_1 Abdomen not enclosed by shell.....4. Moina
  b_2 Shell enclosing the whole abdomen.....5. Ceriodaphnia

1. **Daphnia** O. F. Müller. A sharp caudal spine, extending from the upper posterior angle of shell; head not separated from the body by a dorsal notch: about 50 species.

D. minnehaha Herrick. Caudal spine less than half the length of the shell; general form oval, tapering behind; length 1.8 mm.; a project-

ing spur present on the dorsal margin of the head, which in males and young females has from 1 to 4 sharp teeth: Wisconsin and Minnesota.

D. pulex DeGeer. The common daphnia (Fig. 516). Body oval, often reddish; a prominent beak on the under side of the head; length 2 mm. or more: very common and widely distributed in America and Europe.

D. hyalina Leydig (Fig. 517). Body oval; caudal spine almost as long as body; head extended forward in a helmet-like crest but very variable in shape and size; length 1.8 mm.: widely distributed in this country and Europe.

2. Scapholeberis Schödler. Body short with a truncated hinder end from the lower margin of which a pair of caudal spines, which are sometimes very short, extend backwards: 6 species.

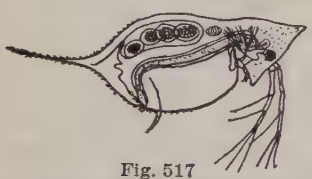

Fig. 517

Fig. 518

Fig. 519

Fig. 517—*Daphnia hyalina* (Herrick). Fig. 518—*Scapholeberis mucronata* (Herrick). Fig. 519—*Simocephalus vetulus* (Süssw. F. Deut.).

S. mucronata (O. F. Müller) (Fig. 518). Spines short; color dark; length .8 mm.: common in eastern America and in Europe.

3. Simocephalus Schödler. Body obliquely truncate behind, without a caudal spine; abdomen with 2 dorsal processes: 8 species.

S. vetulus (O. F. Müller) (Fig. 519). Body large, short, and high; head rounded in front, 2.5 mm. long: common in eastern America; Europe.

S. serrulatus (Koch). Head narrow, extending forwards sharply; length 2 mm.: central United States; Europe.

4. Moina Baird. Head without beak; first antennae long; the end of the abdomen not covered by the shell; pigment spot (accessory eye) absent: about 10 species; in muddy swamps, often in impure water.

Fig. 520—*Moina brachiata* (Herrick).

M. brachiata (Jurine) (Fig. 520). Body almost as high as long, greenish in color; 1.3 mm. long: eastern America; Europe.

5. Ceriodaphnia Dana. No beak present; first antennae short; head rounded; shell oval or circular, and reticulate: about 20 species; often in foul water.

C. reticulata (Jurine). Claws of abdomen dentate; length .8 mm.: eastern and central America; Europe.

Family 3. BOSMINIDAE.

First antennae greatly elongated and extending from the beak forms a long curved proboscis; 5 pairs of feet and rudiments of the sixth; second antennae small; pigment spot (accessory eye) wanting; intestine straight and without liver sacs: 1 genus.

Bosmina Baird. With the characters mentioned above: about 20 species; mostly bottom forms.

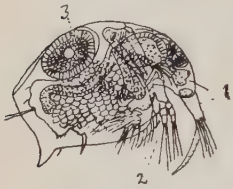

Fig. 521
Bosmina longirostris (Herrick).
1, first antenna; 2, second antenna; 3, egg in the brood sac.

B. longirostris (O. F. Müller) (Fig. 521). Shell oval with hexagonal markings and with a caudal spine projecting from the ventral margin; length .35 mm.: very common in eastern and central America; Europe.

Family 4. LYNCEIDAE.

Second antennae small, each branch of each consisting of 3 segments; pigment spot (accessory eye) very large; intestine bent or coiled and usually without liver sacs: the largest cladoceran family, containing about 20 genera.

Key to the genera of *Lynceidae* here described:

a_1 Intestine not coiled or bent.....1. **Eurycercus**
a_2 Intestine coiled.
  b_1 A dorsal keel on head.....2. **Acroperus**
  b_2 No keel.
    c_1 Body oval or elongate.
      d_1 Outer margin of post-abdomen concave in outline; second antennae with 7 long setae.....3. **Graptoleberis**
      d_2 Outer margin of post-abdomen straight.
        e_1 Terminal claw of abdomen with 1 basal spine.....4. **Alona**
        e_2 Two basal spines present.....5. **Pleuroxus**
    c_2 Body globular; animals minute.....6. **Chydorus**

1. Eurycercus Baird. Body large and oval with short antennae; intestine bent like an S and with liver sacs: 1 species.

E. lamellatus (O. F. Müller) (Fig. 522). Body very large, being sometimes 3 mm. long; hinder side of the abdomen serrate: central states; Europe.

Fig. 522—*Eurycercus lamellatus* (Süssw. F. Deut.).

2. Acroperus Baird. Body minute, elongate, with a long, broad abdomen; head and back with a keel; shell with diagonal markings; intestine coiled: 3 species.

A. harpae Baird (Fig. 523). Body truncate behind; length .7 mm.: widely distributed over eastern and central America; Europe; common.

3. Graptoleberis Sars. Body minute, elongate; posterior margin straight; second antennae with 7 long setae: 1 species.

G. testudinaria (Fischer) (Fig. 524). Length .7 mm.; shell reticulate: eastern and central America; Europe.

4. Alona Baird. Body minute, more or less oval or rectangular in form, with small antennae, the second having 8 setae; with a coiled intestine: numerous species, which are very variable in form.

A. quadrangularis (O. F. Müller) (Fig. 525). Body oval or quadrangular; pigment spot smaller than eye, abdomen very broad and short;

Fig. 523

Fig. 524

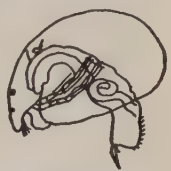

Fig. 525

Fig. 523—*Acroperus harpae* (Herrick). Fig. 524—*Graptoleberis testudinaria* (Süssw. F. Deut.). Fig. 525—*Alona quadrangularis* (Süssw. F. Deut.).

shell smooth and yellowish in color; length .9 mm.: widely distributed over eastern and central America; Europe.

5. Pleuroxus Baird. Front end of head long and pointed, forming a beak; shell with an arched dorsal edge; intestine coiled: numerous species.

P. procurvus Birge (Fig. 526). Hinder margin of shell denticulate; beak curved upwards, forming a hook; length .5 mm.: eastern and central America.

6. Chydorus Leach. Body minute, spherical, with a long curved beak; antennae short; intestine coiled: 8 species.

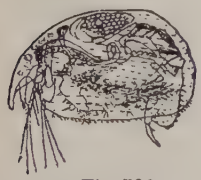

Fig. 526

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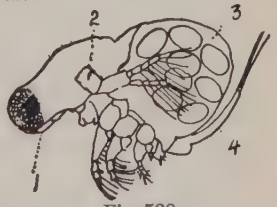

Fig. 528

Fig. 526—*Pleuroxus procurvus* (Herrick). Fig. 527—*Chydorus sphericus* (Herrick). Fig. 528—*Polyphemus pediculus* (Süssw. F. Deut.). 1, first antenna; 2, second antenna; 3, brood sac; 4, abdomen.

C. sphericus (O. F. Müller) (Fig. 527). Shell reticulated; pigment spot almost as large as the eye; color yellowish; length .4 mm.: widely distributed over eastern and central America; Europe.

Family 5. POLYPHEMIDAE.

Carapace not enclosing the legs and abdomen, and serving only as a brood sac; 4 pairs of legs which lack the flattened respiratory projections of other *Phyllopoda;* abdomen slender, with 2 long caudal spines; head very large, with a single large eye and large second antennae: 4 genera.

Key to the genera of *Polyphemidae* here described:

a_1 Fresh-water animals.....1. POLYPHEMUS
a_2 Marine animals.....2. EVADNE
b_1 Head and thorax continuous dorsally.
b_2 Head and thorax separated by a notch.....3. PODON

Fig. 529

Fig. 530

Fig. 529—*Evadne nordmanni* (Sharpe). A, female; B, male.
Fig. 530—*Podon leuckarti* (Sharpe).

1. **POLYPHEMUS** O. F. Müller. Head separated from thorax by a dorsal depression: 2 species.

P. pediculus (L.) (Fig. 528). Length 1 mm.; body highly colored but transparent: usually in deep lakes and rivers; a back-swimmer; widely distributed throughout America and Europe.

2. **EVADNE** Lovén. Head and thorax not separated by a dorsal depression; brood sac very high; antennae small: 3 species; marine.

E. nordmanni Lov. (Fig. 529). Outer branch of third pair of legs with a single spine; length 1.15 mm. or less; colorless: very common along the Atlantic coast.

3. **PODON** Lilljeborg. Head and thorax separated by a dorsal depression: several species; marine.

P. leuckarti (Sars) (Fig. 530). Length 1 mm.; both branches of the second antennae with 6 bristles each: common along the Atlantic coast occurring with the preceding; Europe.

FAMILY 6. LEPTODORIDAE.

Shell rudimentary and not covering the legs or the long, segmented abdomen; 6 pairs of cylindrical legs, the first pair being much larger than the others; 2 terminal claws on the abdomen: 1 genus.

LEPTODORA Lilljeborg. With the characters mentioned above: 1 species.

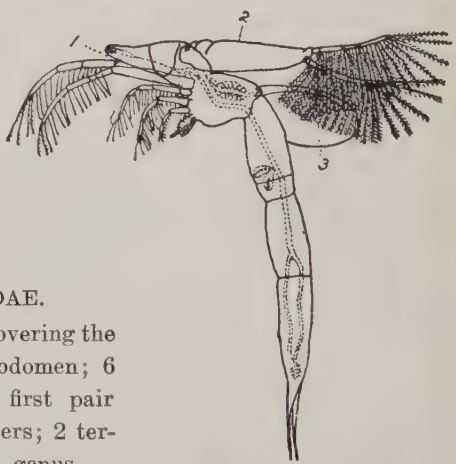

Fig. 531 — *Leptodora hyalina*. 1, first antenna; 2, second antenna; 3, shell.

L. hyalina Lillj. (Fig. 531). Body elongate; first antennae small in female, but very long in male; length 9 mm.; transparent: in clear fresh-water lakes in America and Europe; it comes to the surface usually only on dark nights.

Order 2. COPEPODA.*

Body elongated, the thorax and abdomen being usually distinctly segmented, and made up of 15 somites, 5 of which are united to form the head and 5 form each the thorax and the abdomen. The head and thorax together form the cephalothorax. In many forms fusion takes place between the head and the first thoracic somite, or between the fourth and the fifth thoracic somites, so that but 4 free thoracic segments are then present. The abdominal somites are also often united in the female, the first and second invariably. The last abdominal segment ends with the furca, a pair of terminal projections bearing a definite number of long caudal bristles. In the parasitic copepods the form and structure of the body have often been profoundly changed, and all semblance to the typical copepod form may have been lost. Ten pairs of appendages are present, 5 of which are cephalic and 5 thoracic. The first pair of antennae is uniramose and is longer than the second and may be used for locomotion; in the male either one or both of the first pair are often modified to form clasping organs. The second pair is biramose (but occasionally uniramose) and sometimes provided with prehensile hooks and spines. A poisonous sting is present in front of the mouth in *Argulus*. The thoracic appendages are biramose swimming legs (Fig. 542, 6), which are without gills. Except in the *Pontellidae* and the *Argulidae* a single median eye is present.

The genital openings are in the first abdominal segment: except in the *Argulidae* the female carries her eggs in 1 or 2 gelatinous masses, the so-called egg sacs, which project from the segment into the water. The young animal is born as a nauplius.

More than 2,200 species of copepods are known, of which nine-tenths are marine. About half of these are non-parasitic and form one of the most important elements in the plankton, because of their enormous numbers: they are among the most important scavengers of the sea and form besides the principal food of herrings and many other fishes. The parasitic copepods are called fish lice and live on the external surface and gills of fishes and occasionally on squids and other animals. The order contains about 20 families grouped in 2 suborders.

* See "Die freilebenden Copepoden," etc., by C. Claus, 1863. "Deutschlands freilebende Süsswasser Copepoden," by O. Schmeil, Bibliotheca Zoologica, 1892-1896. "Synopsis of the Entomostraca of Minnesota," etc., by C. L. Herrick, Sec. Rep. of State Zool., 1895. "Copepoda of the Woods Hole Region," by W. M. Wheeler, Bull. U. S. Fish. Com. for 1899, Vol. 19, p. 157. "Freshwater Copepoda of Mass.," by A. S. Pearse, Am. Nat., Vol. 40, p. 241, 1906. "Notes on Marine Copepoda of R. I.," by L. W. Williams, Am. Nat., Vol. 40, p. 639, 1906. "Süsswasserfauna Deutschl.," Heft 11, 1909. "Notes on the Marine Copepoda and Cladocera of Woods Hole," etc., by R. W. Sharpe, Proc. U. S. Nat. Mus., Vol. 38, p. 405, 1911.

Key to the suborders of *Copepoda:*

a_1 The female carries egg sacs.....1. EUCOPEPODA
a_2 No egg sacs present.....2. BRANCHIURA

SUBORDER 1. EUCOPEPODA.

Body elongate; mouth parts biting in the free and sucking in most of the parasitic forms: 15 families.

Key to the families of *Eucopepoda* here described:

a_1 Free-swimming forms (with a few exceptions).
b_1 First antennae 17 to 25-jointed, being very long, usually as long as the body; but 1 egg sac.
c_1 First antennae prehensile in male; animals marine.....1. CALANIDAE
c_2 Right first antenna prehensile; marine and fresh-water animals.
d_1 First pair of legs normal; but 1 eye present.....2. CENTROPAGIDAE
d_2 First pair of legs weak or rudimentary; 3 eyes usually present.
3. PONTELLIDAE
b_2 First antennae not more than 17-jointed; usually 2 egg sacs.
c_1 Abdomen markedly narrower than thorax; 2 egg sacs; mostly fresh-water animals.....4. CYCLOPIDAE
c_2 Abdomen not markedly narrower than thorax.....5. HARPACTICIDAE
a_2 Parasitic forms, but which may usually be free-swimming at times.
b_1 Segmentation distinct.
c_1 Body with the usual number of segments; first antennae 5 to 7-jointed.
c_2 Segmentation indistinct and irregular. 6. ERGASILIDAE
d_1 Body wide and flat.....7. CALIGIDAE
d_2 Body elongate.....8. DICHELESTIIDAE
b_2 Segmentation wanting or indistinct in the egg-bearing female.
c_1 Legs rudimentary; proboscis present; body worm-like.....9. LERNÆIDAE
c_2 Legs rudimentary or wanting; no proboscis present; body worm-like.....10. CHONDRACANTHIDAE
c_3 Legs wanting; proboscis present; body thick and sac-like.
11. LERNÆOPODIDAE

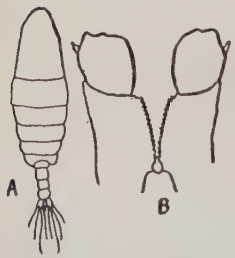

Fig. 532—*Calanus finmarchicus* (Wheeler). A, dorsal aspect of female; B, basal portion of fifth pair of legs.

FAMILY 1. CALANIDAE.*

Body elongate; first antennae very long, with 23 to 25 joints, in the male but slightly modified; second antennae large and biramose; first 4 pairs of legs biramose, outer branch 3-jointed; fifth pair either like the preceding or modified and unlike on the two sides; heart present; a single egg sac present: 26 genera, and over 100 species, all marine.

1. CALANUS Leach. Thorax composed of either 4 or 5 segments, the last one being sometimes asymmetrical; first antennae 25 jointed in the female: many species.

C. finmarchicus (Gunnerus). Brit (Fig. 532). Length about 4 mm.; color yellowish or reddish, but sometimes absent; thorax of 5 segments; fifth pair of legs biramose; first antennae as long as the body: New Eng-

* See "Copepoda," by W. Giesbrecht and O. Schmeil, Das Tierreich, 1898.

land coast, a widely spread, pelagic species, sometimes so abundant that the sea is colored yellow or red, and of great economic importance because it forms an important source of food of herring and mackerel, as well as of the Greenland whale.

C. minor Claus. Length about 1.8 mm.; thorax of 4 segments; fifth pair of legs biramose; first antennae not as long as the body: Gulf stream, off New England, a widely spread species.

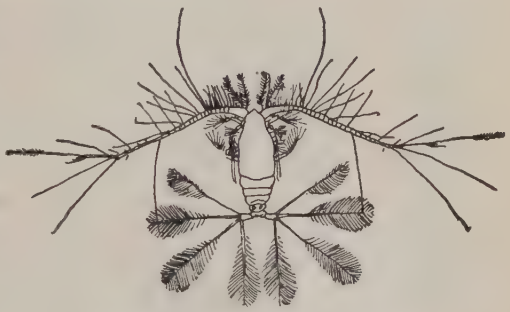

Fig. 533—*Calocalanus pavo* (Wheeler).

2. Calocalanus Giesbrecht. Thorax of female consists of 3 segments, the first somite being fused with the head, and the fourth with the fifth somite; abdomen of female of 2 or 3 segments; abdomen of male of 5 segments; caudal spines very long and plumose: 3 species.

C. pavo (Dana) (Fig. 533). Abdomen of female of 2 segments; caudal bristles symmetrical, branched, and spreading; length 1 mm.; body transparent and reddish: a tropical species which may be found in the Gulf stream off New England.

Family 2. CENTROPAGIDAE.*

Body elongate; first antennae very long, with 23 to 25 joints in the female; the right one (sometimes the left) in the male being prehensile; second antennae large and biramose; heart present; first 4 pairs of legs biramose, the outer branch being 3-jointed, the inner branch 1 to 3-jointed; fifth pair of legs biramose, often modified for clasping; a single egg sac present: about 25 genera and 200 species; in salt and fresh water.

Key to the genera of *Centropagidae* here described:

a_1 Marine animals.
  b_1 First antennae with 24 segments.
    c_1 Thorax of 5 segments ..... 1. Centropages
    c_2 Thorax of 4 segments ..... 2. Temora
  b_2 First antennae with 23 segments ..... 3. Metridia
a_2 Both marine and fresh-water animals.
  b_1 First antennae with 25 segments; fifth feet biramose .... 4. Limnocalanus
  b_2 First antennae with 24 segments; fifth feet uniramose ..... 5. Eurytemora
a_3 Fresh-water animals; first antennae with 25 segments.
  b_1 Fifth feet uniramose; abdomen asymmetrical ..... 6. Epischura
  b_2 Fifth feet biramose; inner branch of first pair of feet 2-jointed. 7. Diaptomus

* See "The North American Centropagidae," etc., by F. W. Schacht, Bull. of Ill. St. Lab., Vol. 5, p. 225, 1898.

1. Centropages Kröyer. Thorax of 5 segments; abdomen of male of 5, of female of 4 segments; first antennae with 24 segments; the 2 branches of all 5 pairs of legs 3-jointed: 13 species; marine.

Fig. 534 *Centropages typicus*—dorsal aspect of female (Wheeler).

C. typicus Kr. (Fig. 534). Fifth thoracic segment with 2 lateral projections; first abdominal segment of female with 4 thorn-like bristles; length 2 mm.; color reddish or bluish, translucent: coast of New England; Europe.

2. Temora Baird. Furca long and slender; furcal bristles short; thorax of 4 segments; abdomen of male of 5, of female of 3 segments; first antennae with 24 segments; the 2 branches of the 5 pairs of legs 2 to 4-jointed: 5 species; marine.

T. longicornis (O. F. Müller) (Fig. 535). Length 1.5 mm.: Woods Hole; very common, especially in the winter; Europe.

3. Metridia Boeck. Thorax of 4 segments, abdomen of male with 3 segments; first antennae with 23 segments; the 2 branches of the first 4 pairs of legs 3-jointed; of the fifth pair 2 to 4-jointed in female and 5-jointed in the male: 10 species; marine.

M. lucens Boeck (*M. hibernica* Brady and Robertson) (Fig. 536). Length 2.5 mm.: New England coast; Europe.

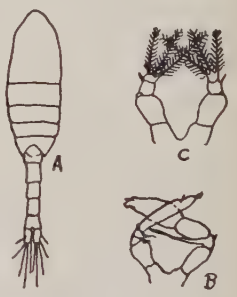

Fig. 536—*Metridia lucens* (Wheeler). A, dorsal aspect of male; B, fifth pair of legs of male; C, fifth pair of legs of female.

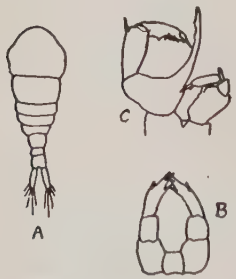

Fig. 535—*Temora longicornis* (Wheeler). A, dorsal aspect of female; B, fifth pair of legs of female; C, fifth pair of legs of male.

4. Limnocalanus G. O. Sars. Thorax of 5 segments; abdomen in female with either 3 or 4 segments, in male with 5; body slender; furca very long; first antennae 25-jointed; all the legs biramose, both branches 3-jointed, except the outer branch of male, which may be 2-jointed: 3 species; in fresh and salt water.

L. macrurus G. O. Sars. Right outer branch of fifth foot in male indistinctly 3-jointed with a hook-like process on second segment; length 2 mm.; color hyaline: cosmopolitan; often common in deep lakes; Europe.

5. Eurytemora Giesbrecht. Thorax of 5 segments; abdomen of male with 5, of female with 3 segments; first antennae about as long as

the thorax and 24-jointed; fifth feet uniramose: 7 species; in fresh, brackish, and salt water.

E. hirundoides (Nordquist) (Fig. 537). Last thoracic segment of female with 2 large projections; length 1.16 mm.; transparent, with yellow bands: Gulf of Mexico and its estuaries, abundant; Boston and Narragansett Bays; Europe.

Fig. 537
Eurytemora hirundoides (Herrick).

6. **Epischura** Forbes. Thorax of 5 segments; abdomen 4-jointed in female, in male 5-jointed, asymmetrical and with prehensile processes on right side; first 4 pairs of legs biramose, the outer branch 3-jointed, the inner branch 1-jointed; fifth pair uniramose, prehensile in male: 3 species; in fresh water.

E. lacustris Forbes. Length 1.7 mm.; second abdominal segment as long as the rest of the abdomen: in deep lakes; central and western America.

7. **Diaptomus*** Westwood. Thorax usually of 5 segments; abdomen of male with 4, female with 3 segments; first antennae with 25 joints; inner branch of first pair of legs 2-jointed, outer branch 3-jointed; both branches of legs 2 to 4 are 3-jointed; fifth pair irregular in form, the inner branch being often rudimentary, the outer branch usually 4-jointed in the female, and 5-jointed in the male: about 80 species, of which 34 are American; in fresh water.

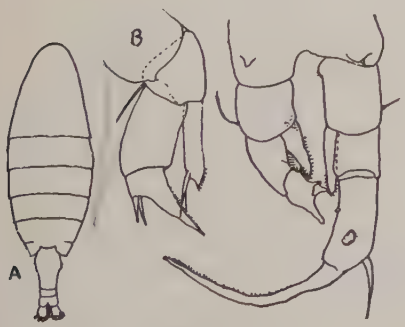

Fig. 538

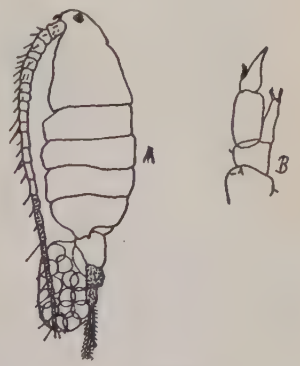

Fig. 539

Fig. 538—*Diaptomus oregonensis* (Pearse). A, dorsal aspect of female; B, fifth leg of female; C, fifth leg of male. Fig. 539—*Diaptomus leptopus*. A, lateral aspect of body (Herrick); B, fifth leg of female.

D. oregonensis Lilljeborg (Fig. 538). Body small, 1.5 mm. long; first abdominal segment of female expanded and equal in length to rest

* See "The North Am. Species of Diaptomus," by F. W. Schacht, Bull. Ill. St. Lab., Vol. 5, p. 97, 1897. "A revision of the North Am. Species of Diaptomus," by C. D. Marsh, Trans. Wis. Acad. Sci., Vol. 15, p. 381, 1907.

of abdomen; cephalothorax widest in the middle: widely distributed and common over the entire northern part of the country.

D. leptopus Forbes (Fig. 539). First antennae about as long as the body; thorax of 4 segments; length 1.5 mm.; body transparent, with purple bands, especially on the terminal portion of the antennae and the abdomen: common in the central states.

D. sanguineus Forbes. Body bright red and 2 mm. long; last thoracic segments with strong lateral spines, and a dorsal hump; first abdominal segment with strong lateral spines: central and eastern United States; common; it occurs only in the early spring, in stagnant pools.

D. minutus Lilljeborg. Body small, 1 mm. long, and slender; thorax of 4 segments; antepenultimate joint of first antennae with a long slender process; terminal hook of right fifth feet in male broad: common in the Great Lakes and widely distributed in northern America; Europe.

Family 3. PONTELLIDAE.

Body elongate, with 4 thoracic segments; first antennae very long, the right one in the male being prehensile; second antennae large and

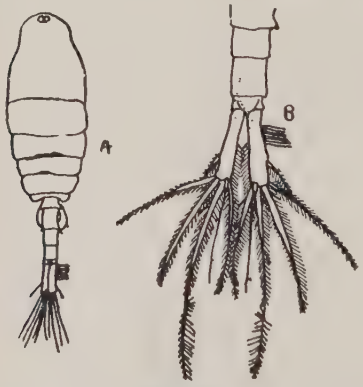

Fig. 540

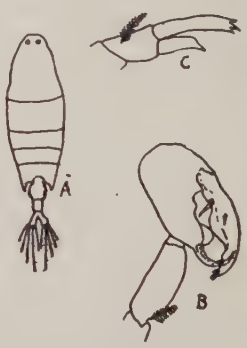

Fig. 541

Fig. 540.—*Tortanus setacaudatus* (Williams). A, dorsal aspect of female; B, abdomen. Fig. 541.—*Labidocera wstira* (Wheeler). A, dorsal aspect of female; B, fifth leg of male; C, right fifth leg of female.

biramose; first pair of legs weak or rudimentary; heart present; median eye and also often paired eyes present; but 1 egg sac: 10 genera and over 70 species; marine.

Key to the genera of *Pontellidae* here described:

a_1 First antennae 23-jointed.....2. Labidocera
a_2 First antennae 17-jointed.
b_1 The 2 branches of the second antennae of equal length.....1. Tortanus
b_2 These branches of unequal length.....3. Acartia

1. **Tortanus** Giesbrecht. First antennae of female 17-jointed; abdomen of female consists of 2 or 3 and of the male of 5 segments; the 2

branches of the second antennae of about the same length; 1 large dorsal eye present; fifth pair of legs uniramose: several species.

T. setacaudatus Williams (Fig. 540). Length of female 1.4 mm.; thorax of 5 segments; fifth pair of feet 2-jointed in female and 3-jointed in male: Narragansett Bay; common.

2. **Labidocera** Lubbock. Thorax of 4 segments; abdomen of female of 2 or 3, of male of 5 segments; first antennae of female of 23 segments; eyes present, a dorsal pair and a ventral median eye: about 14 species.

L. æstiva Wheeler (Fig. 541). Length 2 mm.; body transparent; last thoracic segment in male sometimes asymmetrical: Woods Hole; common.

3. **Acartia** Dana. First antennae of female 17-jointed, of uniform thickness throughout; thorax of 4 segments; 1 large dorsal eye present; abdomen of female of 3 segments; outer branch of second antennae much shorter than the inner; 18 species.

A. tonsa Dana. Length 1.3 mm.; body transparent: Atlantic and Pacific Oceans; often very common; a widely distributed species.

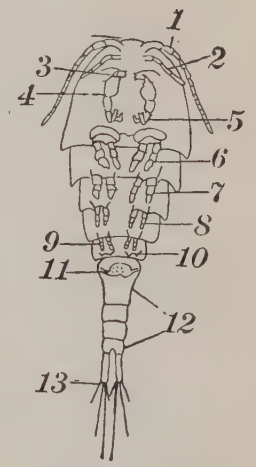

Fig. 542 — Diagram of Cyclops (altered from Süssw. F. Deut.). 1, first antenna; 2, second antenna; 3, mandibles; 4, first maxilla; 5, second maxilla (maxilliped); 6, 7, 8, 9, the first four pairs of thoracic legs, each leg being composed of a basal piece, the protopodite, and two terminal pieces, the exopodite and endopodite; 10, the fifth pair of thoracic legs; 11, receptaculum seminis, in the first abdominal segment; 12, abdomen; 13, furca.

Family 4. CYCLOPIDAE.*

Thorax with 4 free segments, first antennae usually about two-thirds the length of the body, both being modified in the male to serve as prehensile organs; second antennae short and uniramose; first four pairs of feet biramous, outer branch 3-jointed, inner branch 1 to 3-jointed; fifth pair of feet rudimentary, alike in both sexes, rudiments of a sixth pair sometimes present; heart absent; 2 egg sacs present: about 75 species and 5 genera, mostly in fresh water.

1. **Cyclops**† O. F. Müller (Fig. 542). Thorax with 4 free segments, abdomen with 5 segments in the male and 4 in the female; first antennae

* See "A Contribution to a Knowledge of North Am. Fresh-Water Cyclopidae," by E. B. Forbes, Bull. Ill. St. Lab., Vol. 5, 1897.

† See "A Revision of the North American Species of Cyclops," by C. D. Marsh, Trans. Wis. Acad. Sci., Vol. 16, p. 1067, 1909. "The Distribution of the Genus Cyclops in the Vicinity of Haverford, Pennsylvania," by Reynold A. Spaeth, Proc. Acad. Nat. Sci., Vol. 66, p. 20, 1914.

with not more than 17 and second antennae with 4 segments: over 50 species, about 18 being American, all in fresh water, although some species occur also in brackish and even in salt water; many species are extremely variable in form.

Key to the species of *Cyclops* here described:

a_1 First antennae 17-jointed.
  b_1 First antennae not reaching the hinder border of head segment..C. VIRIDIS
  b_2 First antennae reaching beyond this point.
    c_1 Fifth feet with 2 long plumose terminal bristles.....C. LEUCKARTI
    c_2 Fifth feet with 2 smooth terminal bristles.....C. BICUSPIDATUS
    c_3 Fifth feet with 3 terminal bristles.....C. ALBIDUS
a_2 First antennae 12-jointed.....C. SERRULATUS
a_3 First antennae 10 or 11-jointed.....C. PHALERATUS

C. leuckarti Claus (*C. edax* Forbes) (Fig. 543). Body slender and 1.3 mm. long; first abdominal segment very long, equaling the other 3; first antennae 17-jointed; fifth feet 2-jointed, the second joint with 2 very long bristles, the outer one springing from the middle of the segment, the first joint also with a bristle: very common in the Great Lakes and in all parts of the country; Europe.

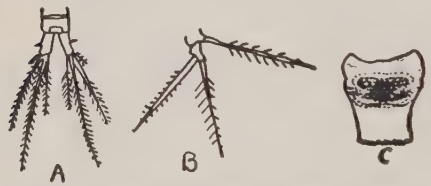

Fig. 543—*Cyclops leuckarti* (Süssw. F. Deut.). A, furca and furcal bristles; B, fifth foot; C, receptaculum seminis.

C. viridis Jurine (Fig. 544). Body 1.5 to 5 mm. long and variable in color, usually greenish; first antennae 17-jointed and very short, hardly reaching the hinder border of the head; fifth feet 2-jointed with a very broad basal joint, each joint bearing a plumose bristle. This species, which occurs also in Europe, is usually the commonest one in small ponds throughout the country. It is extremely variable, the 2 principal varieties being *C. viridis* var. *brevispinosus* Herrick, which tends to the larger size, and *C. viridis* var. *americanus* Marsh (*C. insectus* Forbes), the smaller and more numerous one.

Fig. 544—*Cyclops viridis* (Süssw. F. Deut.). A, furca and furcal bristles; B, fifth foot; C, receptaculum seminis.

C. bicuspidatus Claus (*C. pulchellus* Sars; *C. forbesi* Herrick) (Fig. 545). Body slender and 1.3 mm. long; first antennae 17-jointed; fifth feet 2-jointed, the terminal joint with 2 terminal bristles; furca and caudal bristles very long: very common over the entire country, in lakes and rivers, being one of the commonest pelagic cyclops in the Great Lakes; Europe.

C. albidus Jurine (*C. signatus* Herrick) (Fig. 546). Body 1.4 mm. long, and banded with blue or green; first antennae 17-jointed; fifth feet 2-jointed, the first joint being longer than broad, the second joint with 3 terminal bristles: common throughout the country in clear lakes; Europe.

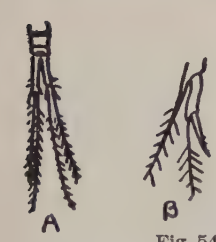

Fig. 545

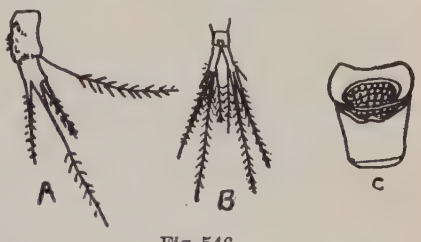

Fig. 546

Fig. 545—*Cyclops bicuspidatus* (Süssw. F. Deut.). A, furca and furcal bristles; B, fifth foot; C, receptaculum seminis. Fig. 546—*Cyclops albidus* (Süssw. F. Deut.). A, fifth foot; B, furca and furcal bristles; C, receptaculum seminis.

C. serrulatus Fischer (Fig. 547). Body 1.4 mm. long, rather opaque; first antennae 12-jointed; fifth feet 1-jointed and plate-like, with 3 terminal bristles: very common everywhere; Europe.

C. phaleratus Koch (Fig. 548). Body 1.2 mm. long, brown in color with blue feet; antennae 10 or 11-jointed and very short, not reaching beyond the middle of the head: not common, but generally distributed in shallow lakes and stagnant pools; Europe.

Fig. 547

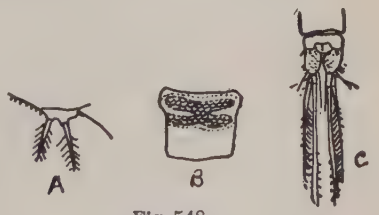

Fig. 548

Fig. 547—*Cyclops serrulatus* (Süssw. F. Deut.). A, fifth foot; B, furca of male; C, receptaculum seminis. Fig. 548—*Cyclops phaleratus* (Süssw. F. Deut.). A, fifth foot; B, receptaculum seminis; C, furca and furcal bristles.

2. **Oithona** Baird. Head terminating with a beak-like process; abdomen with 4 or 5 segments; first antennae in part indistinctly jointed and with very long bristles; second antennae 2-jointed: marine.

O. similis Claus. Beak bent down at right angles to head; caudal setae not plumose; body .75 mm. long and usually colorless: Woods Hole; Narragansett Bay; Europe.

Family 5. HARPACTICIDAE.

Minute, elongate copepods with a cylindrical body, the thoracic segments not being much larger than the abdominal; first antennae short, 4

to 10-jointed, in the male modified and prehensile; second antennae usually biramose; fifth pair of feet 1 or 2-jointed and serving as egg support in the female; heart absent; usually a single egg sac present: about 30 genera and 150 species, mostly marine, usually found among vegetation.

Key to the genera of *Harpacticidae* here described:

a_1 Fresh-water animals.....1. CANTHOCAMPTUS
a_2 Marine animals.
b_1 The outer branch of the first pair of legs much longer than the inner. 2. HARPACTICUS
b_2 The inner branch longer than the outer.....3. ECTINOSOMA

1. CANTHOCAMPTUS Westwood (Fig. 549). Thorax of 4 segments; head with a rostrum; first antennae with 6 to 9 joints, usually 8 in the female; abdomen 5-jointed in the male and 4 in the female: mostly in fresh water; about 6 American species.

Fig. 549 Diagram of *Cantho-camptus* (Süssw. F. Deut.).

C. minutus Claus. Body 1 mm. long; first antennae 8-jointed; legs 3-jointed in both branches, except the fifth leg, which is 2-jointed: eastern and central states; common, especially in muddy pools; Europe.

2. HARPACTICUS Milne-Edwards. Outer branch of the first leg 3-jointed, almost twice as long as the 2-jointed inner branch; conical rostrum present; third pair of legs with very strong outer branch: 12 species; marine.

H. chelifer (O. F. Müller). Length of male 1 mm.; first pair of legs with 1 spine, outer branch with 3; inner caudal spines longer than the cephalothorax: Atlantic coast; Europe.

3. ECTINOSOMA Boeck. First antennae 5 to 7-jointed; first pair of legs scarcely smaller than the others and with the inner branch longer than the outer; fifth pair of legs 2-jointed: 12 species.

E. curticorne Boeck. Length .7 mm.; color dark brown; first antennae very short, 6-jointed: common in Narragansett Bay; Europe.

4. PARATEGASTES G. O. Sars. First antennae 6 or 7-jointed; second antennae with a 1-jointed outer branch; last pair of legs very large in the female, with an expansion on the basal joint.

P. sphæricus Claus. Length .35 mm.; color brown: abundant in Narragansett Bay; Europe.

FAMILY 6. ERGASILIDAE.*

Body more or less cylindrical, somewhat like *Cyclops* in shape, usually well segmented; first pair of antennae 5 to 7-jointed, second 3 or

* "North American Parasitic Copepods Belonging to the Family Ergasilidae," by C. B. Wilson, Proc. U. S. Nat. Mus., Vol. 39, p. 263, 1911.

4-jointed and modified to form a pair of large hooks for prehensile purposes; female carries a pair of long egg sacs and is parasitic, usually on the gills of fresh-water fishes: about 10 genera and 85 species; about 15 species known in America.

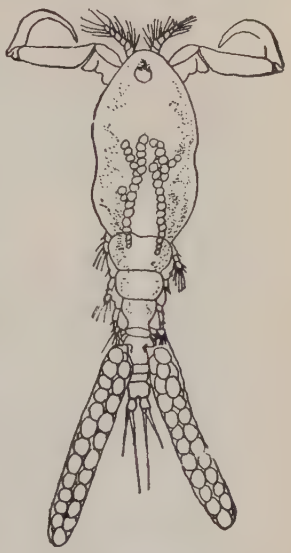

Fig. 550—*Ergasilus versicolor* (Wilson).

Ergasilus von Nordmann. Cephalothorax pear-shaped, fifth pair of legs rudimentary: several species.

E. versicolor C. B. Wilson (Fig. 550). Length 1.5 mm.: parasitic on the gills of the common bullhead and three kinds of catfish.

Family 7. CALIGIDAE.*

Body wide and flat, the segmentation being more or less obliterated and the female being larger than the male; first antennae short, with 2 to 3 joints; second antennae in form of short hooks; mouth parts form a suctorial beak; first 4 pairs of legs usually biramose and facilitate rapid swimming; fifth pair reduced or wanting; 2 long egg sacs with the eggs in a single row in each: about 35 genera and 200 species, which are parasitic externally on fishes.

Fig. 551—*Caligus rapax* (Wilson). 1, sucker; 2, egg sac.

Key to the genera of *Caligidae* here described:

a_1 A pair of suckers at front end of body. .1. Caligus
a_2 No suckers present . . . . . .2. Lepeophtheirus

1. Caligus O. F. Müller. First and fourth pairs of legs uniramose, second and third biramose; body composed of 4 parts, a cephalothorax, a thorax, a genital segment, and an abdomen; a pair of suckers at the base of the first antennae: 17 American species.

C. rapax Milne-Edwards (Fig. 551). Free thoracic segment small and narrower than the genital segment, which in the female is about twice as wide as the abdomen; length of female about 6 mm.: the commonest species, occur-

* See "North Am. Parasitic Copepods Belonging to the Family Caligidae," etc., by C. B. Wilson, Proc. U. S. Nat. Mus., Vol. 28, p. 479, 1905; Vol. 31, p. 669, 1907; Vol. 33, p. 323, 1908.

ring on the cod, flounder, and more than 25 other kinds of marine fishes.

2. **Lepeophtheirus** von Nordmann. Similar to *Caligus* but without the suckers: 12 American species.

L. edwardsi C. B. Wilson (Fig. 552). End segment less than half as long as the genital segment and 1-jointed; length of female about 7 mm.: on flounders and other fish.

Fig. 552
Lepeophtheirus edwardsi (Wilson).

Family 8. DICHELESTIIDAE.

Body usually elongated and flattened, with segmentation partially obliterated; first antennae delicate and usually many-jointed; second antennae in form of long hooks; hinder pair of legs usually reduced: about 20 genera and 60 species, which are parasitic on fishes, principally selachians.

Dichelestium Hermann. First 2 pairs of legs small and biramose, third pair broad and plate-like, fourth and fifth wanting; first antennae 8-jointed: 3 species, in fresh and salt water.

D. sturionis Herm. Length 2 cm.: on the gills of sturgeons; Vineyard and Long Island Sounds.

Family 9. LERNÆIDAE.

Body very different in form at different periods; during the breeding period the animals swim about freely, and the body consists of a large cephalothorax, a thorax bearing 4 pairs of biramose legs, and an elongate abdomen; after fertilization the female changes into an unsegmented, worm-like creature with minute legs and projections at the forward end representing the antennae, and with a pair of egg sacs projecting from the hinder end; the front end is imbedded in the body of the fish on which it lives: about 50 species.

1. **Lernæa** L. The pairs of legs of the swimming individuals close together; body of egg-bearing female twisted S-shape, with a pair of egg sacs.

L. branchialis L. Length extended, 4 cm.; egg sacs convoluted: on the gills of the cod and other fishes.

2. **Lerneænicus** Lesson. Legs of the swimming forms much reduced and close together; body of adult female elongated, with long egg sacs.

L. radiata Les. (Fig. 553). Length 4 cm.: on the menhaden; common.

Family 10. CHONDRACANTHIDAE.

Female without segmentation and with paired blunt projections representing the appendages, with long egg sacs; male very small, segmented, with 2 pairs of legs, and attach themselves to the body of the female: about 40 species.

Chondracanthus Delaroche. Second antennae form short, stout hooks: about 20 species, parasitic on the gills of marine fish.

C. cornutus (O. F. Müller) (Fig. 554). Body of female elongate, 6 mm. long; length of male .3 mm.: on the gills of the *Pleuronectidae.*

Fig. 553

Fig. 554

Fig. 553 — *Lernæenicus radiata* (Verrill). Fig. 554 — *Chondracanthus cornutus* (Bronn).

Family 11. LERNÆOPODIDAE.*

Body consists of a head and a thorax; antennae small; first two pairs of legs long and forming the organs of attachment; other legs wanting; male minute and attached to the body of the female; female with 2 thick egg sacs: about 60 species.

Lernæopoda Blainville. Head somewhat smaller than the thorax, which is slender and not segmented: about 9 species; in fresh and salt water.

L. fontinalis S. I. Smith. Length of female 4 mm.: on brook trout in Maine.

Suborder 2. BRANCHIURA.

Parasitic copepods with a flattened body consisting of a disc-like cephalothorax, on the dorsal surface of which is a pair of large compound eyes, with a thorax of 3 free segments, and an unsegmented, 2-lobed abdomen; antennae small; mouth parts consisting of a proboscis containing 2 serrate mandibles and 1 pair of slender maxillae; in front of the mouth is usually a poisonous sting projecting from a sheath, into which it can be withdrawn; a large sucker usually present on each side of the proboscis and just behind it a pair of short uniramose appendages, the suckers and the appendages representing the 2 branches of the second maxillae; 4 pairs of large biramose legs; no egg sacs, the eggs being deposited on stones and other objects; the animals leave their hosts occasionally and swim about freely: 1 family and about 37 species.

Family ARGULIDAE.†

With the characters of the suborder: 1 American genus.

* See "North Am. Parasitic Copepods of the Family Lernæopodidae," etc., by C. B. Wilson, Proc. U. S. Nat. Mus., Vol. 47, p. 565, 1915.

† See "North Am. Parasitic Copepods of the Family Argulidae," etc., by C. B. Wilson, Proc. U. S. Nat. Mus., Vol. 25, p. 635, 1903.

Argulus O. F. Müller. Suckers and sting present: 27 species, parasites on marine and fresh-water fish, usually in the branchial cavity; 13 American species.

A. laticauda S. I. Smith. Carapace elliptical, considerably longer than wide and not reaching the abdomen, which is broadly elliptical; length 6 mm.: on the eel, flounder, and other marine fishes; common.

A. catostomi Dana & Herrick. Carapace round, wider than long, and reaching the abdomen, which is round and wider than long; length 12 mm.; color light green: on fresh-water fish, especially the sucker (New England).

A. funduli Kröyer. Carapace wider than long and not reaching the abdomen, which is very long, being 3 times as long as wide; length 5 mm.: on *Fundulus* along the Atlantic coast.

A. versicolor C. B. Wilson (Fig. 555). Length 6 mm.; width 4.9 mm.; color brilliantly variegated: in gill cavity of pickerel.

Order 3. OSTRACODA.*

Body without segmentation and laterally compressed, and entirely enclosed in a bivalved carapace. The two sides of the carapace can be closed by a retractor muscle; when they open, the appendages are thrust out and propel the animal through the water. Seven pairs of appendages are present (Fig. 556, B). The two pairs of antennae are used for both locomotion and orientation, the second pair being either biramose or uniramose. The mandibles have each a large 3 or 4-jointed palp; two pairs of maxillae are present, of which the second pair are usually leg-like. Two pairs of legs follow, the second pair sometimes being bent back and apparently of use only in keeping dirt out of the shell. The abdomen is short and may end in a projection with two terminal claws called the furca. The internal

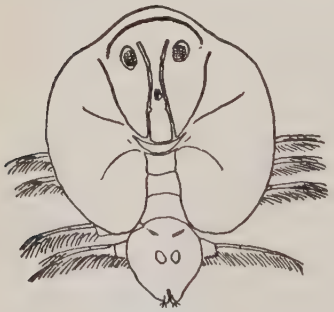

Fig. 555—*Argulus versicolor* (Wilson).

* "A Monograph of the Marine and Freshwater Ostracoda," by G. S. Brady, and A. M. Norman, Trans. Royal Dublin Soc. Vols. 4 and 5, 1889 and 1896. "Synopsis of Freshwater Ostracoda," by C. H. Turner, Am. Nat., Vol. 33, p. 877, 1899. "Rep. on the Freshwater Ostracoda of the U. S.," etc., by R. W. Sharpe, Proc. U. S. Nat. Mus., Vol. 26, p. 969, 1903. "Marine Ostracoda of Vineyard Sound and Adjacent Waters," by J. A. Cushman, Proc. Bost. Soc. Nat. Hist., Vol. 32, p. 359, 1906. "The Ostracoda of the San Diego Region, II, Littoral Forms," by C. Juday, Univ. Cal. Pub., Vol. 3, p. 135, 1907. "Die Süsswasserfauna Deutschlands," Heft 11, 1911. "Ostracoda," by G. W. Müller, Das Tierreich, 1912.

organs are distinguished by their compactness. A heart is usually absent. A single median eye or a pair of eyes close together is usually present, but the *Cypridinidae* have an additional pair of large compound eyes. Ostracods are unisexual animals, most of which lay eggs which they either attach to water plants, as in the case of *Cypris,* or, as in *Cypridina,* carry between the shells until they hatch. *Cypris* and certain other genera are parthenogenetic, in certain species no males having yet been discovered. The *Cypridae* and *Cytheridae* are born as nauplii, in which the bivalved shell is already present; the other ostracods are born later than the nauplius stage. The *Ostracoda* live on or near the bottom of both salt and fresh water, where they crawl or swim actively about and feed principally on small animals. *Entocythere* is parasitic on the crayfish. The order contains 2 suborders and more than 1,400 species, of which the great majority are marine, the *Cypridae* being the only family which lives almost exclusively in fresh water.

Key to the suborders of *Ostracoda:*

a_1 Second antennae apparently uniramose.....1. PODOCOPA
a_2 Second antennae biramose, one branch large, the other minute; marine.
2. MYODOCOPA

SUBORDER 1. PODOCOPA.*

Second antennae apparently uniramose and bearing sharp bristles, which are of use in swimming or walking; heart absent; shell without antennal sinus: 2 families; mostly in fresh water.

Key to the families of *Podocopa:*

a_1 The 2 pairs of thoracic feet dissimilar, second pair bent back....1. CYPRIDAE
a_2 The 2 pairs of thoracic feet and the second maxillae all locomotory and similar .....2. CYTHERIDAE

FAMILY 1. CYPRIDAE.

Shell thin; first antennae 8-jointed, but appearing 6 or 7-jointed, and with long bristles; second antennae apparently uniramose, the exopodite being a minute plate with 3 bristles, and leg-shaped and 3 to 6-jointed, with several long natatory bristles on the second and also the last joint; usually a single eye present; manibular palp 4-jointed; first maxilla with a 2-jointed palp; second maxilla small, with a short palp, which is prehensile in the male; first pair of legs locomotory, the second bent back and not locomotory; abdomen with a furca; genital organs large, extending into the space between the shells: about 350 species, mostly in fresh water.

* See "Contributions," etc., by R. W. Sharpe, Bull. Ill. St. Lab., Vol. 4, 1897.

Key to the genera of *Cypridae* here described:

a_1 Second antennae with natatory bristles.
  b_1 Animals in fresh water.
    c_1 Second foot terminates with 1 long straight and 1 short curved bristle.
      d_1 Caudal furca long, each side with 2 terminal bristles.....1. CYPRIS
      d_2 Caudal furca rudimentary.....2. CYPRIDOPSIS
    c_2 Second foot terminates with 2 straight bristles.....3. CYPRIA
  b_2 Animals marine.....5. PONTOCYPRIS
a_2 Second antennae without natatory bristles; animals cannot swim.
  4. CANDONA

1. **CYPRIS** O. F. Müller. Eye single, median; second antennae 5-jointed, the 5 natatory bristles extending to the tip of the terminal

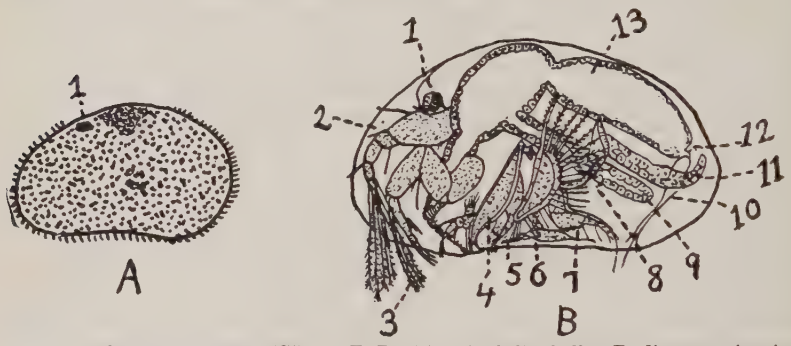

Fig. 556—*Cypris virens* (Süssw. F. Deut.). A, left shell; B, diagram showing organs. 1, eye; 2, first antenna; 3, second antenna; 4, mandible; 5, first maxilla; 6, second maxilla; 7, first leg; 8, second leg; 9, liver; 10, abdomen; 11, ovary; 12, anus; 13, intestine.

bristles; first maxilla with a large and second maxilla with a small branchial plate; parthenogenetic, the males being unknown: about 8 American species.

C. virens (Jurine) (Fig. 556). Length 1.69 mm.; height .95 mm.; breadth .9 mm.; shell highest just back of the eye and covered with short

Fig. 557

Fig. 558

Fig. 559

Fig. 557—*Cypris fuscata* (Süssw. F. Deut.). Fig. 558—*Cypridopsis vidua* (Süssw. F. Deut.). Fig. 559—*Cypria exculpta* (Sharpe).

hairs; dorsal side bluish-black; lateral sides greenish with yellowish areas extending diagonally downwards from the region of the eye: cosmopolitan.

C. fuscata Jurine (Fig. 557). Length 1.5 mm.; height .9 mm.; breadth .7 mm.; shell reniform and greenish-brown in color with pellucid spots and a bluish-black patch on either side: cosmopolitan.

2. Cypridopsis Brady. Eye single, median; second antennae 5-jointed, the natatory bristles extending beyond the terminal bristles; caudal furca rudimentary; males unknown: 11 species, 3 American.

C. vidua O. F. Müller (Fig. 558). Length .6 mm.; height .34 mm.; width .4 mm.; color yellowish-green with 3 transverse bands on the back and sides: common everywhere in fresh water; a scavenger.

3. Cypria Zenker. Body compressed; eye single, median; second antennae 5-jointed, the 5 natatory bristles very long, extending far beyond the terminal bristles; furca normal, stout: 11 species, 7 American.

C. exsculpta Fischer (Fig. 559). Length .58 mm.; height .38 mm.; width .26 mm.; shell thin, somewhat transparent and covered with a meshwork of longitudinal lines; furca bent: common in shallow ponds and slowly flowing, shallow streams; Europe.

4. Candona Baird. Second antennae of female 5-jointed and lacking the natatory bristles; furca strong: on the bottom, in the mud and sand, not being able to swim; 25 species, 9 American.

Fig. 560
Candona acuminata
(Süssw. F. Deut.).

C. acuminata Fischer (Fig. 560). Length 1 mm.; height .44 mm.; width .36 mm.; shell pointed behind, white or brown in color; the shorter bristle of the last segment of second foot 3 or 4 times as long as the last segment: often common; Europe.

Fig. 561—*Pontocypris edwardsi* (Cushman).

5. Pontocypris Sars. First antennae 7-jointed with bristles longest on the last joint and decreasing in length proximally; second antennae with 4 slender claws on last joint and a group of 5 bristles on the antepenultimate: several species; marine.

P. edwardsi Cushman (Fig. 561). Shell somewhat triangular with rounded ends, hirsute; first antennae with 4 bristles from basal joint; length .85 mm.; height .47 mm.: Eel Pond, Woods Hole, in August.

Family 2. CYTHERIDAE.

Shell usually calcareous and hard; eyes paired but more or less confluent, sometimes wanting; first antennae 5 to 7-jointed, with bristles; second antennae leg-like, 4 or 5-jointed, with 2 terminal claws; with a basal segment bearing a long flagellum which contains a duct from a poison gland; mandible with palp; first maxilla normal, second maxilla leg-like and similar to the 2 pairs of legs; furca rudimentary; animals cannot swim: about 700 species and 30 genera, almost exclusively in salt water; 8 American marine and 2 fresh-water genera.

Key to the genera of *Cytheridae* here described:

a_1 Animals marine.
  b_1 Dorsal and ventral margins of shell not parallel.....1. LOXOCONCHA
  b_2 Margins of shell nearly parallel.
    c_1 Surface of shell rough.....2. CYTHEREIS
    c_2 Surface of shell smooth.....3. PSEUDOCYTHERETTA
a_2 Fresh-water animals.
  b_1 Animals free-swimming.....4. LIMNICYTHERE
  b_2 Animals parasitic.....5. ENTOCYTHERE

1. **LOXOCONCHA** Sars. Shell with a notch at the dorso-posterior angle; ends and ventral margin extended into a flattened rim; first antennae 6-jointed, with a group of slender setae on the last joint; second antennae 4-jointed: 2 American species; marine.

L. impressa (Baird) (Fig. 562). Length .82 mm.; height .51 mm.: Vineyard Sound; very common in shallow water, among eel grass, hydroids, etc.

2. **CYTHEREIS** Sars. Shell strongly calcareous; first antennae 5 or 6-jointed; second antennae 4-jointed, with a short flagellum in the female; first pair of feet differing on the two sides of the body in the male: 10 American species; marine.

C. arenicola Cushman (Fig. 563). Shell quadrangular, the dorsal and ventral margins being almost parallel, 1 mm. long; .5 mm. high; surface with irregular patches, usually each with a single hair: common on sandy bottoms in Vineyard Sound.

Fig. 562

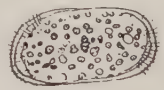

Fig. 563

Fig. 564

Fig. 562—*Loxoconcha impressa* (Cushman). Fig. 563—*Cythereis arenicola* (Cushman). Fig. 564—*Pseudocytheretta edwardsi* (Cushman).

3. **PSEUDOCYTHERETTA** Cushman. Inner border of shell irregular; flagellum of second antennae 3-jointed; first foot of male with a seta on the hinder border; left and right first feet of male very different: 1 species.

P. edwardsi Cushman (Fig. 564). Dorsal and ventral margins of shell nearly parallel, with rounded hairy ends; length 1.2 mm.; width .61 mm.: Vineyard Sound in rather deep water, the commonest ostracod of the region.

4. **LIMNICYTHERE** Brady. First antennae 5-jointed with short bristles on the outer edge; second antennae 4-jointed; mandible with large branchial plate: 2 American species, both in Illinois.

L. reticulata Sharpe (Fig. 565). Length .68 mm.; height .35 mm.; breadth .25 mm.; color whitish; shell with conspicuous polygonal markings.

5. **Entocythere*** Marshall. First antennae 6-jointed, with long jointed bristles; second antennae 4-jointed; mandible with branchial plate: 1 species.

Fig. 565—*Limnicythere reticulata*—inside of left shell (Sharpe).

E. cambaria Marsh. Body oval, .6 mm. long; shell thin and smooth: parasitic on gills of *Cambarus* in Wisconsin.

Suborder 2. MYODOCOPA.

Second antennae biramose, one branch being large and many-jointed and usually with natatory bristles, the other minute; front margin of shell with a deep notch in front for the protrusion of the second antennae: 5 families, marine.

Key to the families of *Myodocopa* here described:

a_1 Eyes present.....1. Cypridinidae
a_2 Eyes absent.....2. Halocypridae

Family 1. CYPRIDINIDAE.

Shell with a deep notch in front (antennal sinus); 3 eyes present; first antennae stout, 5 to 8-jointed, bearing the large sense organ; second antennae with outer branch usually 9-jointed; inner branch in male 3-jointed; mandibular foot 5-jointed, terminating in a claw: 2 American genera.

Fig. 566
Sarsiella zostericola (Cushman).
1, antennal sinus.

Sarsiella Norman. Shell of female without notch; first antennae 5-jointed, with sense organ on third joint in male: 2 American species.

S. zostericola Cushman (Fig. 566). Shell 1.3 mm. long and .86 mm. high in the male and 1.1 mm. long and 1 mm. high in the female, obliquely truncate behind: on eel grass and hydroids at Woods Hole.

Family 2. HALOCYPRIDAE.†

Shell very thin and flexible with notch (antennal sinus) in front, above which is a rostrum; median tentacles present between first antennae; eyes absent: 3 American genera, all on the Pacific coast.

1. **Halocypris** Dana. Rostrum very short, notch small; shell short and high: 1 American species.

* See "Entocythere cambaria, a Parasite Ostracod," by W. S. Marshall, Trans. Wis. Acad. Sci., Vol. 14, pt. 1, p. 117.

† See "Ostracoda of the San Diego Region, I. Halocypridae," by C. Juday, Univ. Cal. Pub., Vol. 3, p. 13, 1906.

H. pelagica Claus (Fig. 567). Shell 1.4 mm. long and 1.1 mm. high; first antennae strongly curved: Atlantic and Pacific Oceans.

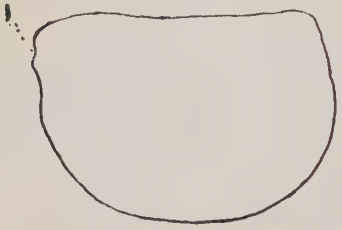

Fig. 567—*Holocypris pelagica* (Juday). 1, antennal sinus.

2. **Conchœcia** Dana. Shell elongate with well-developed rostrum and notch: 7 American species.

C. magna Claus. Shell subquadrangular, higher behind than in front, 2.6 mm. long and half as high; dorsal margin with a depression near the middle: widely distributed in the Atlantic and Pacific Oceans.

Order 4. CIRRIPEDIA.*

Body usually of large size and enclosed in a calcareous shell; animals marine and sessile as adults, living either attached to rocks, timbers, or seaweed, or as parasites on or in the bodies of crabs, mollusks, or other marine animals. A cement gland in the penultimate joint of each anterior antenna furnishes a secretion by means of which the barnacles are attached; the parasitic *Rhizocephala* fasten themselves to their hosts by means of long root-like projections of the head. The body, like that of the *Ostracoda,* is entirely enclosed in a carapace which arises on the back of the head and thorax and falls in a right and left fold over the body, forming the characteristic shell. The appendages are a pair of mandibles, two pairs of maxillae, and six pairs of biramose and plumose thoracic appendages or legs. It is these legs which project from the shell and give the animal its characteristic appearance. In some of the parasitic cirripeds the number of pairs of thoracic legs is less than 6 and in the *Rhizocephala* both they and the mouth parts are altogether wanting. The abdomen is rudimentary. The digestive tract in the barnacles passes straight to the anus at the hinder end of the abdomen; in the *Rhizocephala* no digestive tract is present, the nutriment being absorbed through root-like projections of the stalk which entwine the viscera of the crab on which the parasite is living.

With a few exceptions all cirripeds are hermaphroditic, a condition which is undoubtedly correlated with their sessile habit of life. In a few genera of barnacles (*Ibla, Scalpellum*) complementary males also occur, which live in or near the genital openings of the hermaphroditic individuals. *Scalpellum ornatum, Ibla cummingi,* and all the species of the genera *Cryptophialus* and *Alcippe,* which burrow in the shell of

* See "A Monograph of the Subclass Cirripedia," by Charles Darwin, 1851-1854. "The Barnacles (Cirripedia) Contained in the Collections of the U. S. National Museum," by H. A. Pilsbry, Bull. 60, U. S. Nat. Mus., 1907.

snails, are unisexual, the male being a minute animal, consisting of little but genital organs, which lives a parasitic life on the body of the female. Cirripeds are born as nauplii and pass through a later larval stage possessing a bivalve shell, a pair of compound and a simple eye, called the cypris stage, during which they attach themselves.

History.—The thick, calcareous shells of barnacles have always made them conspicuous objects, and they have been well-known animals for a very long time. The medieval zoologists supposed the *Lepadidae* to be the young of bernicle geese, which often appear in large flocks along the seashore of Europe, and this belief led them to call the animals goose barnacles. It was not until the beginning of the eighteenth century that this belief disappeared. The cirripeds were usually classified with the mollusks by the earlier zoologists, although Lamarck in 1802 placed them among the crustaceans, until J. V. Thompson in 1830 showed the barnacle larva to be a nauplius and thus definitely proved their crustacean nature. Cuvier, however, in 1830 still placed them among the mollusks.

About 500 species of *Cirripedia* are known, of which about 15 species occur on our Atlantic coast. The order contains 5 suborders.

Key to the suborders of *Cirripedia* here described:

a_1 Body enclosed in a calcareous shell; barnacles.....1. THORACICA
a_2 Body without a calcareous shell; animals parasitic.
b_1 Thoracic appendages present; animals bore into the shells of mollusks and cirripeds.....2. ABDOMINALIA
b_2 Thoracic appendages wanting; parasitic on decapods....3. RHIZOCEPHALA

SUBORDER 1. THORACICA.

Barnacles. Body enclosed in a calcareous shell and attached at the dorsal side of the head, the 6 pairs of biramose, tendril-like thoracic legs being thrust out as the shell opens to gather in the small animals and organic fragments which form the food: about 4 families.

Key to the families of *Thoracica:*

a_1 Body attached by a long, thick stalk.
b_1 Stalk almost or quite as wide as the rest of the body, and scaly. 1. MITELLIDAE
b_2 Stalk much narrower than body.....2. LEPADIDAE
a_2 No stalk present.
b_1 On rocks, timbers, etc.....3. BALANIDAE
b_2 On whales.....4. CORONULIDAE

FAMILY 1. MITELLIDAE.

Stalk with scales or spines and as wide as the rest of the body, or nearly so; shell consists of a large number (18 or more) of pieces; mostly hermaphroditic, *Scalpellum ornatum* on the South African coast

and *Ibla cummingi* in the Philippines, however, being unisexual with complementary males, and *Scalpellum vulgare* of the European seas hermaphrodite also with complementary males; *Lithotrya* bores into rocks and mollusk shells and coral: about 10 species.

Fig. 568—Diagram of *Mitella* (Pilsbry). Explanations as in Fig. 570.

1. Mitella Oken (*Pollicipes* Leach) (Fig. 568). Shell consists of from 18 to over 100 pieces, of which the carina, the terga, and the scuta are the largest; hermaphroditic: 8 species.

M. polymerus (Sowerby). Shell composed of upwards of 180 pieces arranged in several whorls, decreasing in size from above downwards; total length 7 cm.: west coast of America; common.

2. Scalpellum Leach (Fig. 569). Stalk thick, short, and usually scaly; shell composed of 12 to 15 pieces; either unisexual or hermaphroditic, with complementary males: 140 species; mostly in deep water.

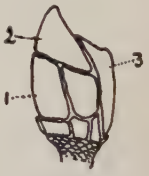

Fig. 569 Diagram of *Scalpellum* (Pilsbry). Explanations as in Fig. 570.

S. strœmi Sars. Stalk about half as long as body and covered with imbricated scales; total length 12 mm.: in deep water in the gulf of Maine, and to the northward; Europe.

Family 2. LEPADIDAE.

Stalk much narrower than the rest of the body and without scales; body flattened and usually covered with a shell consisting of 5 pieces, a pair of large scuta at the stalk end of the body, a pair of smaller terga at the opposite end and a median dorsal carina which lies along the hinge, the shell opening and the legs protruding on the ventral side; *Anelasma*, which lives parasitically in the skin of dogfish in the North Sea, is without a shell; hermaphroditic, without complementary males: about 7 genera and 30 species, which attach themselves usually to floating objects.

Fig. 570 *Lepas anatifera* (Pilsbry). 1, scutum; 2, tergum; 3, carina.

1. Lepas L. Goose barnacles (Fig. 570). Scuta broad and triangular; terga and carina well developed, the latter reaching posteriorly between the former and all 5 parts of the shell abutting on one another: about 6 species, 5 American, all of which are found on both coasts.

L. fascicularis Ellis and Solander. Stalk short, not as long as the body; plates thin and paper-like; carina bent at right angles; length

of shell 4 cm.: cosmopolitan, often very numerous, especially in early summer, on the North American coast, sometimes as far north as the Bay of Fundy, attached to seaweed and other floating objects; Pacific coast north of San Francisco.

L. anserifera L. Stalk about as long as the body; plates radially grooved; length of shell 5 cm.: cosmopolitan.

L. anatifera L. (Fig. 570). Stalk usually as long as or longer than the body; shell bluish-white; plates faintly striated; length of shell 5 cm. or less: cosmopolitan; on ships' bottoms and floating objects; the commonest species; more southerly than *L. fascicularis.*

Fig. 571
Conchoderma virgatum (Pilsbry).

2. Conchoderma Olfers. Carina and terga small or wanting; scuta narrow, the parts of the shell not touching one another; stalk long and almost as broad as the body, tapering from it to the point of attachment: usually attached to ships' bottoms, but also to other objects; 3 species.

C. virgatum (Spengler) (Fig. 571). Length, including stalk, 5 cm.; color grayish, with 6 dark longitudinal bands: cosmopolitan.

Family 3. BALANIDAE.

Rock barnacles. No stalk present; body enclosed in a thick calcareous shell; this is made up of a number of pieces which are joined together to form a cylinder, in which the animal lies on its back with the 6 pairs of thoracic feet uppermost; 2 pairs of hinged plates, corresponding to the scuta and terga of *Lepas,* close the aperture of the cylinder and, on opening, permit the legs to be thrust out and sweep in particles of food: incrusted on rocks and timbers, etc., often in great numbers; about 7 genera and 75 species.

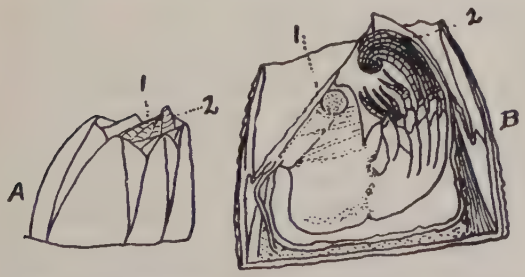

Fig. 572—Diagram of *Balanus* (Darwin). A, entire shell; B, the animal within the shell. Explanations as in Fig. 570.

Balanus L. (Fig. 572). Cylindrical shell composed of 6 thick pieces joined by thinner ones; basis of the shell either membranous or calcareous: about 46 species, of which 8 occur on the Atlantic coast.

B. balanoides (L.). The common barnacle. Base of shell membranous; tergum with a spur; cylindrical shell of variable shape and

with longitudinal ridges; length up to 5 cm.: North Atlantic coast, extremely common between tide lines.

B. eburneus Gould. Ivory barnacle. Shell low and broad in form and with a smooth, white exterior; base of shell calcareous: common from Massachusetts Bay to the West Indies, chiefly below low-water mark; often in brackish and even fresh water.

B. crenatus Bruguière. Shell white, up to 34 mm. high and 19 mm. wide; base calcareous and very thin: Atlantic coast, on stones and shells in deeper water, also on ships.

B. tintinnabulum (L.). Shell often ribbed longitudinally, reddish or bluish in color with a calcareous base; up to 6 cm. in diameter and in length: cosmopolitan, in the warmer seas, often brought to our coast on the bottoms of vessels; is eaten in many countries.

Family 4. CORONULIDAE.

Similar to the preceding family but differing in that the terga and scuta, although freely movable, are not hinged with one another; base of shell membranous: on *Cetacea;* 4 genera and 7 species.

Coronula Lamarck. Shell formed of 6 principal pieces and wider than high; terga and scuta much smaller than the opening: 3 species, on whales.

C. diadema L. Shell crown-shaped, scuta present, terga very small or wanting: off the New England coast.

Suborder 2. ABDOMINALIA.

Body segmented, surrounded by a voluminous mantle but without a shell, and with only 3 pairs of feet on the hinder part of the thorax; unisexual; the animal bores into the shells of mollusks and cirripeds: 2 families.

Family ALCIPPIDAE.

Stalk weak and with a large chitinous disc of attachment; legs uniramose; mantle opens on the side; males minute, without legs, attached to the females: 1 genus.

Alcippe Hancock. With the above-mentioned characters: 1 species.

A. lampas Hancock. Length 6 mm.; bores in dead *Natica* shells which are inhabited by hermit crabs: Woods Hole.

Suborder 3. RHIZOCEPHALA.

Body without segmentation, appendages, or shell and sac-shaped, with a stalk composed of branched thread-like projections which extend into the body of the host; without intestine; hermaphroditic, with comple-

mentary males: 2 families with about 6 genera and 35 species. The best-known genera are *Sacculina* Thompson, with about 6 species, which live on decapod crabs, forming a thick sac between the abdomen and thorax, and *Peltogaster* Rathke, with about 7 species, which live on hermit crabs. They occur in the North Atlantic off the European coast.

Subclass 2. MALACOSTRACA.*

Crayfish, lobsters, and crabs, and the other higher and larger crustaceans. In all, excepting the *Phyllocarida,* the body is made up of 20 somites, of which 5 form the head, 8 the thorax, and 7 the abdomen. The head is invariably fused with one or more thoracic somites, and together with these, in the *Phyllocarida* and *Thoracostraca,* is covered by a shield-like carapace (Fig. 625, 5). The number of pairs of appendages is typically 19, of which 5 are cephalic, 8 are thoracic, and 6 are abdominal: the last abdominal somite, which is called the telson, bears no appendages. The cephalic appendages are the first and second pairs of antennae, one pair of mandibles, and two pairs of maxillae. The terminal portion of the antenna is called the flagellum (Fig. 576, 1): in many cases more than one may be present, one of which may be a smaller or so-called secondary flagellum. The basal portion of the antenna is called the peduncle (Fig. 576, 2). The exopodite of the second antenna is broad and flat in many forms and is called the antennal scale (Fig. 615, 3).

From one to five of the anterior pairs of thoracic appendages are specially modified to assist in eating and are called maxillipeds, while the posterior pairs are called periopods and are used principally for locomotion (Fig. 576, 5). The thoracic appendages are often prehensile and used for grasping, in which case the distal segments may be modified in one of three ways: (1) the terminal segment may form with the next one a forceps-like pinching claw or chela as in the crayfish or crab, when the appendage is spoken of as chelate (Fig. 573, B); (2) the terminal segment may simply bend back on the next one as in the *Amphipoda,* when the appendage is spoken of as subchelate (Fig. 573, A); (3) the terminal segment may be sharp and spine-like, as in the parasitic isopods. The abdominal appendages are called pleopods or swimmerets (Fig.

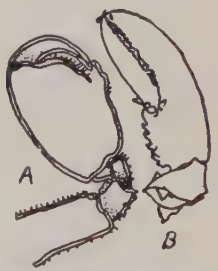

Fig. 573.—Diagrams of *malacostracan* claws. A, a subchelate claw (Smallwood); B, a chelate claw (Herrick).

* See "Natural History of Economic Crustaceans," etc., by R. Rathbun, Bull. of U. S. Fish Com. for 1889, p. 763. "Higher Crustacea of New York City," by F. P. Paulmeier, Bull. 91 of N. Y. St. Mus., 1905. "Die Süsswasserfauna Deutschlands," Heft 11, 1910.

579, 4) and have a variety of functions, being locomotory and respiratory and often serving for the attachment of the eggs or the young. The appendages are all primarily biramose except the anterior antennae, although in the adult animal either the exopodite or the endopodite may be absent and the appendages thus become uniramose. The eyes are either pedunculate or not. The subclass contains 3 divisions and over 11,200 species.

Key to the divisions of *Malacostraca:*

a_1 Abdomen composed of 8 segments; large carapace present..1. PHYLLOCARIDA
a_2 Abdomen of 7 segments or less.
b_1 Carapace absent; thorax usually with 7 free segments....2. ARTHROSTRACA
b_2 Carapace present covering a part or all of the thorax...3. THORACOSTRACA

DIVISION 1. PHYLLOCARIDA.*

Primitive *Malacostraca* with a thorax bearing 8 pairs of leaf-like gills, a long abdomen composed of 8 segments bearing 6 pairs of appendages and with a large carapace enclosing the head, thorax, and a portion of the abdomen; eyes pedunculate: 2 genera and 7 species, all marine.

NEBALIA Leach. Caudal fork (furca) with lateral spines: 4 species.

N. bipes (Fabricius) (Fig. 574). Body slender, compressed, 10 mm. long; genital opening on the last thoracic segment in the male and on the antepenultimate segment in the female; eggs carried by the female between the thoracic feet: North Atlantic, in shallow water, among seaweeds; Europe.

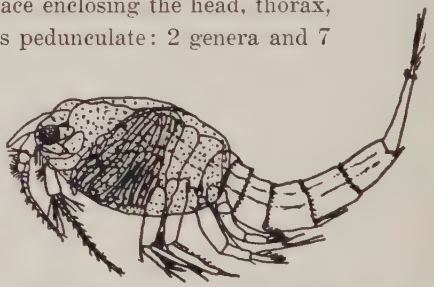

Fig. 574—*Nebalia bipes* (Packard).

DIVISION 2. ARTHROSTRACA.

Malacostracans of small but not minute size in which the first thoracic somite (in a few cases the second also) is united with the head, the remaining 7 being free and appearing as distinct segments; no carapace present; abdominal somites more or less coalesced, 6 free segments usually appearing, although the number is very often smaller; appendages well developed, consisting, when all are present, of 2 pairs of antennae, 1 pair of mandibles, 2 pairs of maxillae, 1 pair of maxillipeds (belonging to the first thoracic segment which is fused with the head), 7 pairs of periopods and 6 of pleopods; eyes in most cases ses-

* See "The Order Phyllocarida," etc., by A. S. Packard, Twelfth Ann. Rep. U. S. Geol. Sur. for year 1878, pt. 1, 1883, p. 432. "The Crustacean Nebalia," by A. S. Packard, Am. Nat., Vol. 16, p. 861.

sile; the eggs are carried on the ventral surface of the thorax in a brood pouch formed by flat projections of the thoracic legs and the young animals are like the parents in form, there being no metamorphosis: 2 orders.

Key to the orders of *Arthrostraca:*

a_1 Usually laterally compressed; very often jumping animals....1. AMPHIPODA
a_2 Usually dorsoventrally flattened; many terrestrial and many parasitic.
2. ISOPODA

ORDER 1. AMPHIPODA.*

Body elongated and usually laterally compressed; first 2 pairs of periopods, which are called gnathopods (Fig. 577, 3 and 4), usually larger than the others and subchelate, being used for grasping the food; gills on the periopods; hinder 3 pairs of pleopods usually adapted for jumping: about 45 families and 2,300 species, which are almost exclusively marine, many species dwelling on the seabeach, burrowing in the sand or living under stones or decaying vegetation; food consisting mostly of living or dead animals of all kinds, also of decaying vegetable matter; a number of species are parasitic; 3 suborders.

Key to the suborders of *Amphipoda:*

a_1 Seven free thoracic segments.
b_1 Head very large, with very large eyes.....1. HYPERIIDEA
b_2 Head and eyes not of unusual size.....2. GAMMARIDEA
a_2 Six free thoracic segments; abdomen very rudimentary.....3. CAPRELLIDEA

SUBORDER 1. HYPERIIDEA.

Head and eyes both very large; maxilliped without a palp; 7 pairs of thoracic legs present: parasitic or living on or in pelagic animals, especially medusae; 4 families.

Key to the families of *Hyperiidea* here described:

a_1 Usually found in medusae.....1. HYPERIIDAE
a_2 In the tests of *Salpa* or *Pyrosoma*.....2. PHRONIMIDAE

FAMILY 1. HYPERIIDAE.

Head large and almost entirely occupied by the enormous eyes; 5 abdominal segments; mandibular palp present: usually found in large medusae; about 8 genera.

HYPERIA Latreille. Gnathopods feeble: several species in *Aurelia, Cyanea,* and other medusae; 2 species on the Atlantic coast.

H. galba (Montagu). Periopods with very few setae; length 15 mm.: in *Aurelia;* coast of New England.

* See "Synopsis of the Amphipoda," by S. J. Holmes, Am. Nat., Vol. 37, p. 267, 1903. "The Amphipoda 1. Gammaridea," by T. R. R. Stebbing, Das Tierreich, 1906. "The Amphipods of Southern New England," by S. J. Holmes, Bull. of U. S. Fish. Com., Vol. 24, p. 457, 1904. "The Freshwater Amphipoda of North America," by Ada L. Weckel, Proc. U. S. Nat. Mus., Vol. 32, p. 25, 1907.

H. medusarum (O. F. Müller) (Fig. 575). Gnathopods covered with setae on the sides; length 12 mm.: found in *Cyanea* and other jellyfish; coast of New England, north of Cape Cod.

Fig. 575—*Hyperia medusarum* (Leunis).

Family 2. PHRONIMIDAE.

Head very long dorsoventrally, on the sides and top of which are the large eyes; no mandibular palp present; second antennae rudimentary in the female: about 7 genera.

Phronima Latreille. Fifth pair of periopods with large chelae; last thoracic segment elongated: 1 species.

P. sedentaria (Forskal). Length 3 cm.: cosmopolitan; each individual living in the transparent test of *Salpa* or *Pyrosoma*.

Suborder 2. GAMMARIDEA.

Seven free thoracic segments and pairs of thoracic legs; maxilliped with a 2 to 4-jointed palp: about 40 families and over 1,000 species.

Key to the families of *Gammaridea* here described:

a_1 Three last abdominal somites normal and not fused together.
  b_1 Body compressed and not flattened.
    c_1 Last pair of pleopods do not end in a hook.
      d_1 First antennae usually shorter than second.
        e_1 First antennae without secondary flagellum.
          f_1 First antennae much shorter than the second.
            g_1 Two eyes present.....1. Orchestiidae
            g_2 Four eyes present.....3. Ampeliscidae
          f_2 First antennae but little shorter than second.....4. Calliopiidae
        e_2 First antennae with 2 flagella, posterior periopods very broad. 2. Pontoporeiidae
      d_2 First antennae usually longer than second, or of nearly the same length.
        e_1 Secondary flagellum present; both pairs of gnathopods usually of same size.....5. Gammaridae
        e_2 Secondary flagellum usually absent; second pair of gnathopods larger than the first.....6. Photidae
    c_2 Last pair of pleopods end in a hook.....7. Amphithoidae
  b_2 Body flattened, with small abdomen.....8. Corophiidae
a_2 Last 3 abdominal somites fused with caudal stylets.....9. Cheluridae

Family 1. ORCHESTIIDAE.

The beach fleas. First antennae much shorter than the second; mandible without palp; body laterally compressed; second gnathopod much larger than the first: about 13 genera and 100 species, which live largely on the seashore and are more or less adapted to a terrestrial life.

Key to the genera of *Orchestiidae* here described:

a_1 First antennae shorter than peduncle (long basal segments) of second.
  b_1 Dark-colored animals found on the seabeach.....1. Orchestia
  b_2 Whitish animals which burrow in the sand.....2. Talorchestia
a_2 First antennae longer than peduncle of second.....3. Hyalella

1. Orchestia Leach. Dark-colored amphipods in which the first antennae are shorter than the basal portion (peduncle) of the second, and the first gnathopod is subchelate in both sexes: 25 species.

O. agilis S. I. Smith (Fig. 576). First antennae not reaching the tip of the penultimate joint of peduncle of second antenna; length 14

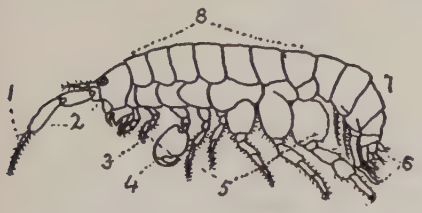

Fig. 576

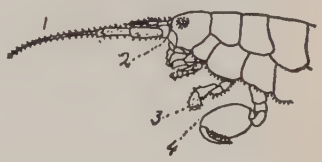

Fig. 577

Fig. 576—*Orchestia agilis* (Verrill). 1, flagellum of second antenna; 2, peduncle; 3, first gnathopod; 4, second gnathopod; 5, periopods; 6, jumping legs; 7, abdomen; 8, thorax. Fig. 577—*Orchestia palustris* (Paulmeier). Explanations as in Fig. 576.

mm.; color brownish: Atlantic coast, under masses of decaying seaweed on the shore, as far south as Florida; when disturbed it hops and runs with great rapidity; Europe.

O. palustris* S. I. Smith (Fig. 577). First antennae reaching beyond tip of penultimate joint of peduncle of the second antennae; length 18 mm.; color brownish: Cape Cod to New Jersey; on the shore of salt marshes; Europe.

2. Talorchestia Dana. Whitish, large amphipods in which the first antennae are shorter than the basal portion (peduncle) of the second and the first gnathopods are subchelate in the male and not in the female: 20 species.

T. longicornis† (Say) (Fig. 578). Eyes large; second gnathopods of male very large; first antennae just reaching to the tip of the penultimate joint of the second antennae; length 25 mm.; color whitish, but sometimes brown: Cape Cod to New Jersey, common on sand beaches, burrowing in the sand in the daytime.

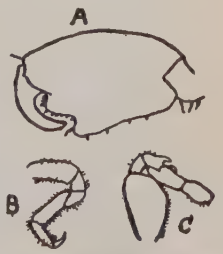

Fig. 578—*Talorchestia longicornis* (Paulmeier). A, second gnathopod of male; B, first gnathopod of female; C, second gnathopod of same.

3. Hyalella S. I. Smith (*Allorchestes* Dana). Small amphipods in which the first antennae are longer than the basal portion (peduncle) of the second: 2 species.

* See "The Salt-Marsh Amphipod, Orchestia palustris," by M. E. Smallwood, Cold Spring Harbor Monographs, III, 1905.

† See "The Beach Flea; Talorchestia longicornis," by M. E. Smallwood, Cold Spring Harbor Monographs, I, 1903.

H. dentata (Say) (Fig. 579). Hinder dorsal margin of the first and second abdominal segments produced to form spines; length 6 mm.: in fresh-water ponds in the eastern states, where it is one of the two common fresh-water species of amphipods, *Gammarus fasiatus* being the other.

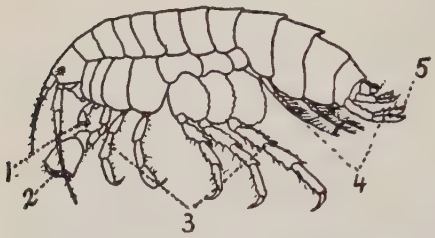

Fig. 579—*Hyalella dentata* (Paulmeier). 1, first gnathopod; 2, second gnathopod; 3, periopods; 4, pleopods; 5, jumping legs.

FAMILY 2. PONTOPOREIIDAE.

First antennae but little shorter than the second and with a secondary flagellum; mandible with a palp; posterior periopods very broad and modified for digging: about 8 genera and 22 species.

HAUSTORIUS St. Müller. Characters as above; small rostrum present: 1 species.

H. arenarius (Slabber) (Fig. 580). Length 18 mm.; color whitish: Georgia to Cape Cod; on the seabeach near high-water mark, where it burrows with great rapidity; Europe.

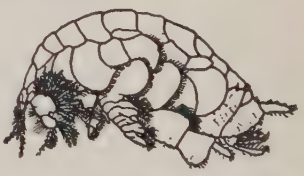

Fig. 580—*Haustorius arenarius* (Paulmeier).

FAMILY 3. AMPELISCIDAE.

First antennae some distance in front of and at least half as long as the second; 4 eyes usually present; last 2 segments of abdomen fused together: a burrowing family with about 3 genera and 40 species.

AMPELISCA Kröyer. Telson divided by a median cleft; 4 eyes present; first antennae about half as long as the second: about 25 species.

A. macrocephala Lilljeborg. Postero-lateral margin of third abdominal segment elongated; head usually as long as the first 3 thoracic segments; length 15 mm.; color white: Vineyard Sound and northwards, living in tubes in the mud; Europe.

A. compressa Holmes. Head considerably shorter than the first 3 thoracic segments; body very compressed; length 6 mm.: common from Cape Cod to Cape Hatteras.

FAMILY 4. CALLIOPIIDAE.

First and second antennae of nearly the same length; periopods rather strongly built, the last 3 pairs increasing successively in length: about 15 genera and 30 species.

Calliopius Lilljeborg. Both pairs of gnathopods large and of equal size; terminal abdominal segment slender and not split: 2 species.

C. læviusculus (Kröyer) (Fig. 581). First and second antennae of nearly the same length; eyes large; length 16 mm.; color light green: Cape Hatteras to Greenland, in tide pools and among seaweed; Europe; North Pacific.

Fig. 581—*Calliopius læviusculus* (Paulmeier).

Family 5. GAMMARIDAE.

Both pairs of antennae long, the first antennae usually longer than the second and with a secondary flagellum which is a small side branch of it; mandible with a palp; both pairs of gnathopods usually of the same size; terminal pleopods extending beyond the others: over 50 genera and 250 species, largely in fresh and brackish waters.

Key to the genera of *Gammaridae* here described:

a_1 Last 3 abdominal segments with small bunches of hairs along hinder margin.
b_1 First 3 abdominal segments not extended behind.....1. Gammarus
b_2 First 3 abdominal segments each extended behind as an acute tooth.
2. Carinogammarus
a_2 No such bunches of hairs on these segments.....3. Elasmopus

1. Gammarus Fabricius. Telson deeply cleft; last 3 abdominal segments with bunches of small hairs: over 30 species; in salt and fresh water; 6 fresh-water species in the United States.

Fig. 582

Fig. 583

Fig. 582—*Gammarus locusta* (Paulmeier). Fig. 583—*Gammarus faciatus* (Paulmeier).

G. locusta (L.) (Fig. 582). First antennae longer than the second; secondary flagellum with about 8 joints; length 20 mm.; color greenish: Arctic Ocean to New Jersey, being very common under stones and in seaweed along the seashore; Europe.

G. annulatus S. I. Smith. First antennae shorter than the second; length 15 mm.; no lateral hairs on the fourth abdominal segment: Long Island Sound to Bay of Fundy.

G. fasciatus Say (Fig. 583). First and second antennae of about the same length; length 15 mm.; color whitish: common in fresh-water ponds and streams, it and *Hyalella dentata* being the common fresh-water amphipods in the eastern states.

2. **Carinogammarus** Stebbing. Telson deeply cleft; last 3 abdominal segments with bunches of small hairs and first 3 each with a dorsal backwards projecting spine: about 9 species.

C. mucronatus (Say) (Fig. 584). Antennae of the same length; length 15 mm.; color greenish: Cape Cod to Florida, common among algae and in brackish water.

Fig. 584

Fig. 585

Fig. 584—*Carinogammarus mucronatus* (Paulmeier). Fig. 585—*Elasmopus lævis* (Paulmeier).

3. **Elasmopus** Costa. First antennae twice as long as the second; first 3 abdominal segments very large, last 3 small and bent beneath them: about 9 species.

E. lævis (S. I. Smith) (Fig. 585). Last 3 pairs of abdominal appendages short and thick; length 10 mm.; color brownish; first gnathopods small, second large: Cape Cod to New Jersey, under rocks and among seaweeds near low-tide mark.

Family 6. PHOTIDAE.

First antennae with or without a small secondary flagellum and longer than the second; mandible with a long palp; second gnathopods larger than the first: 10 genera and about 40 species.

Leptocheirus Zaddach (*Ptilocheirus* Stimpson). Terminal pleopods biramose; both pairs of gnathopods large and chelate; first antennae with a minute secondary flagellum: 8 species.

L. pingius Stim. Body thick, and variegated in color; length .13 mm.: New Jersey to Labrador; common on muddy bottoms.

Family 7. AMPHITHOIDAE.

First antennae with or without secondary flagellum and about the same length as the second; gnathopods large, the second being larger than the first; last pair of abdominal appendages end in hooks: about 6 genera and 30 species.

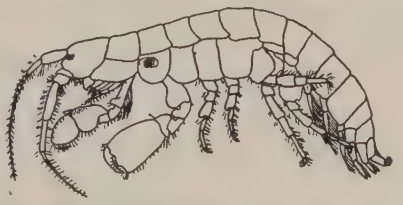

Fig. 586—*Amphithoë valida* (Paulmeier).

Amphithoë Leach. First antennae without secondary flagellum; head without rostrum; mandible with palp: 17 species.

A. valida S. I. Smith (Fig. 586). Antennae of about equal length and less than half as long as body: New Jersey and Long Island Sound under rocks and among seaweed.

A. longimana Smith. First antennae as long as the body; gnathopods stout and elongate; length 9 mm.: common; Cape Cod to New Jersey, among eel-grass.

Fig. 587—*Corophium cylindricum* (Paulmeier).

Family 8. COROPHIIDAE.

Body depressed and abdomen small; first antennae with or without secondary flagellum; second antennae very large: about 11 genera and 45 species; tube-dwelling.

1. Corophium Latreille. Mandibular palp two-jointed; no secondary flagellum; second antennae enormously developed in the male; gnathopods feeble: 12 species.

C. cylindricum (Say) (Fig. 587). Length 5 mm.; color light, sometimes with spots: Maine to New Jersey, living free or in tubes in the mud or in sponges, etc.

Fig. 588
Unicola irrorata
(Paulmeier).

2. Unicola Say. Body depressed; first antennae with secondary flagellum and a little longer than the second; telson lamellar, rounded: 8 species.

U. irrorata Say (Fig. 588). Color red, mottled with white; length 15 mm.; body broad; rostrum distinct: Labrador to New Jersey; common on sandy or rocky bottoms, living in tubes, often not of its own construction.

Family 9. CHELURIDAE.

Body cylindrical; first antennae short, with secondary flagellum; second antennae longer than the first and with blade-like flagellum; 4 abdominal segments; 3 pairs of caudal stylets present, the last pair being nearly as long as the rest of the body, but shorter in the female: 1 genus.

Chelura Philippi. With the characters above given: 1 species.

C. terebrans Phil. Length 6 mm.: New England coast, boring in submerged timbers, and often doing great damage; Europe.

Suborder 3. CAPRELLIDEA.

But 6 free thoracic segments; abdomen very rudimentary; body very elongate: 2 families and about 65 species.

Family CAPRELLIDAE.

Body slender and cylindrical; first antennae longer than the second; gills confined to third and fourth free thoracic segments, on which the legs may be wanting: 2 genera, which live among seaweeds and on hydroids, holding on by the 3 pairs of long posterior thoracic legs, with about 50 species.

Fig. 589 *Caprella geometrica* (Paulmeier).

1. Caprella Lamarck. Five pairs thoracic legs; mandible without a palp; gills and no legs on the second and third free thoracic segments; abdomen reduced to a small knob bearing a pair of rudimentary legs in the male: many species.

C. geometrica Say (Fig. 589). Head with an anteriorly projecting spine; antennae of nearly the same length; length 15 mm.; color variable: Cape Cod to Virginia; very common.

2. Æginella Broeck. Like Caprella but with a palp on the mandible: several species.

A. longicornis Kröyer (Fig. 590). First pair of antennae twice as long as the second; body either smooth or spiny; length 16 mm.; color variable: Labrador to New Jersey; Europe.

Fig. 590—*Æginella longicornis* (Paulmeier).

Order 2. ISOPODA.*

Body usually flattened dorsoventrally and with gills on the abdominal appendages; the anterior pairs of pleopods usually more or less

* See "Synopsis of North American Isopoda," by Harriet Richardson, Am. Nat., Vol. 34, pp. 207 and 295. "Monograph of the Isopods of North America," by same, Bull. U. S. Natl. Mus., No. 54, 1905.

lamellar and functioning as gills or lungs, while the last pair, which are called uropods (Fig. 602) and have a distinct exopodite and endopodite, are elongated and function as feelers or as swimming fins: about 18 families and over 2,300 species, which are small, creeping or swimming animals, most of them marine, living under stones along the seashore and among seaweed or parasitic on fish; a few live in fresh water, while several very familiar species are terrestrial.

Key to the families of *Isopoda* here described:

a_1 First pair of legs chelate.....1. TANAIDAE
a_2 First pair of legs not chelate.
b_1 Uropods lateral.
c_1 Uropods with telson forming a caudal fin; pleopods mostly natatory.
d_1 Exopodite of uropod arches over base of telson.....2. ANTHURIDAE
d_2 Exopodite of uropod does not thus arch.
e_1 Abdomen composed of 6 segments.
f_1 Both branches of uropod well developed.
g_1 Not parasitic; body more or less cylindrical; eyes usually small. 3. CIROLANIDAE
g_2 Parasitic on fish.
h_1 Body broad and flattened; first 3 pairs of legs prehensile..4. ÆGIDAE
h_2 Eyes large; legs all prehensile.....5. CYMOTHOIDAE
f_2 The 2 branches of uropod not of same length, the exopodite being minute; animal bores in wood.....6. LIMNORIIDAE
e_2 Abdomen composed of 2 segments.....7. SPHÆROMIDAE
c_2 Uropods arch over the other pleopods, covering them.....8. IDOTHEIDAE
b_2 Uropods terminal.
c_1 Animals aquatic.
d_1 First antennae much smaller than the second, but not minute.
e_1 Animals not parasitic.
f_1 Fresh-water forms .....9. ASELLIDAE
f_2 Marine forms .....10. JANIRIDAE
e_2 Animals parasitic on decapods.....15. BOPYRIDAE
d_2 First antennae minute and not easily seen.....13. LIGYDIDAE
c_2 Animals terrestrial (occasionally aquatic).
d_1 Cannot roll itself into a ball (except *Cylisticus convexus*).
e_1 End segment of abdomen pointed or angular.....11. ONISCIDAE
e_2 End segment truncate or indented...14. TRICHONISCIDAE
d_2 Can roll itself into a ball.....12. ARMADILLIDIDAE

FAMILY 1. TANAIDAE.

Body more or less cylindrical, with 6 free thoracic segments; first pair of legs chelate; abdominal appendages, when present, natatory; gills on the thoracic appendages: about 16 American species; marine.

Fig. 591 *Tanais cavolini* (Harger).

1. TANAIS Audouin and Edwards. Only 3 pair of pleopods present; uropods uniramose and short: 5 American species.

T. cavolini Milne-Edwards (Fig. 591). Body slender, abdomen with 5 segments; uropods 3-jointed; length 4 mm.; width 1 mm.: Greenland to Long Island Sound; in shallow water on piles and among seaweed.

2. **Leptochela** Dana. Male with large, female with small chelae; 5 pairs of pleopods present; uropods biramose; eyes present: 5 American species.

L. savignyi (Kröyer) (Fig. 592). Chela of male elongated; exopodite of uropods composed of 1, endopodite of 6 segments; length 2 mm.; color white: New Jersey to Cape Cod; among seaweed and at the surface; Europe.

Fig. 592 *Leptochela savignyi* (Harger).

Family 2. ANTHURIDAE.

Body cylindrical and elongate, with 7 free thoracic segments; abdomen relatively short, with its anterior somites often fused together; uropods lateral, large, and expanded, the outer branch (exopodite) arching over the telson: about 15 species, 9 American.

Cyathura Norman and Stebbing. First 5 abdominal segments fused together so as to resemble an eighth thoracic; maxillipeds 3-jointed: 1 American species.

C. carinata (Kröyer) (Fig. 593). Both pairs of antennae short and thick and with few hairs; length 18 mm.; breadth 2 mm.; color brownish or yellowish: New Jersey to Greenland; on sand and mud bottoms in shallow water and among seaweed; Europe.

Fig. 593 *Cyathura carinata* (Harger).

Family 3. CIROLANIDAE.

Body semicylindrical and broad; abdomen composed of 6 segments; uropods lateral, forming with the telson a caudal swimming fin: 23 American species.

Cirolana Leach. First 3 pairs of legs prehensile, last 4 pairs ambulatory; first and second pair similar to each other: 14 American species.

Fig. 594 *Cirolana concharum* (Harger).

C. concharum (Stimpson) (Fig. 594). Length 23 mm.; breadth 8 mm.; telson triangular; base of uropods is extended posteriorly beneath the margin of the telson two-thirds of its length: South Carolina to Nova Scotia on muddy and sandy bottoms in shallow water, feeding on the blue crab and other animals.

Family 4. ÆGIDAE.

Body broad and more or less flattened; head short and broad, usually with 2 very large eyes on its upper surface; first 3 pairs of legs prehensile; uropods lateral and forming a caudal fin with the telson: parasitic on the skin of fish; 30 American genera.

Æga Leach. Body elliptical in outline; basal segments of first antennae expanded and lying entirely in front of the head: 14 American species.

A. psora (L.). Salve bug (Fig. 595). Length 16 mm.; breadth 10 mm.: parasitic on the skate, cod, halibut, and other fishes; used as a salve by fishermen; Long Island Sound to Greenland; Gulf of Mexico; Europe.

Fig. 595
Æga psora
(Harger).

Family 5. CYMOTHOIDAE.

Head triangular, with large eyes, and extending over the base of the short antennae; all 7 pairs of legs prehensile, terminating in hooks: parasitic on fishes; over 100 species, 27 American.

Livoneca Leach. Body elliptical, more or less asymmetrical; first pair of antennae widely separated at the base: 5 American species.

Fig. 596
Limnoria lignorum
(Harger).

L. ovalis (Say). Length 21 mm.; width 13 mm.: parasitic on the gills and in the mouth of the bluefish and occasionally of other fishes along the Atlantic coast south of Cape Cod, and in the Gulf of Mexico.

Family 6. LIMNORIIDAE.

Body flattened and with parallel sides; can roll itself into a ball; antennae short; eyes lateral; uropods lateral; legs ambulatory: 1 genus.

Limnoria Leach. With characters of family: 1 species.

L. lignorum (Rathke). Gribble (Fig. 596). Length 3 mm.; width 1.5 mm.: Florida to Labrador; Europe; Pacific coast; makes burrows about 12 mm. deep in submerged timbers, causing great damage to docks, etc.; very common.

Family. 7. SPHÆROMIDAE.

Body short, oval, and convex, and in many species can be rolled into a ball; but 1 abdominal segment besides the large telson; inner branch of uropod immovable: 30 American species.

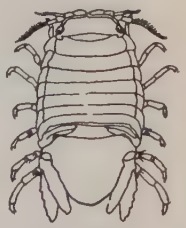

Fig. 597
Sphæroma quadridentatum
(Harger).

Sphæroma Latreille. Uropods large, lateral, the 2 branches being of equal length, the outer margin of the exopodite being denticulate; legs ambulatory: 3 American species.

S. quadridentatum Say (Fig. 597). Body can be rolled into a ball; length 8 mm.; width 4 mm.; color dark and variable: Florida to Cape Cod; under stones between tide lines.

Family 8. IDOTHEIDAE.

Body more or less broad and flattened; often elongate; abdominal segments partially or completely fused; uropods lateral, arching over and covering the other pleopods under the abdomen: about 90 species, 40 American.

Key to the genera of *Idotheidae* here described:

a_1 Side of head cleft and extending beyond eyes.....2. Chiridotea
a_2 Side of head not extended in dorsal view.
b_1 Second antennae with a long flagellum; abdomen of several segments. 1. Idothea
b_2 Second antennae without a long flagellum; abdomen a single segment.
c_1 Second antennae not much longer than head.....3. Edotea
c_2 Second antennae very much longer than head.....4. Erichsonella

1. Idothea Fabricius. Second antennae with a long flagellum and much larger than the first; legs all alike; abdomen composed of 3 complete and 1 partial segment: 8 American species.

Fig. 598
Idothea baltica (Harger).

I. baltica (Pallas) (*I. marina* L.; *I. irrorata* Say) (Fig. 598). Length 20 mm.; width 7 mm.; color often green, but very variable; abdomen ending in three projections: Nova Scotia to North Carolina; cosmopolitan; on seaweed, in sand or at the surface; common.

I. phosphorea Harger. Length 21 mm.; width 7 mm.; color variable; abdomen tapering to a point: coast of New England, among rocks and seaweed.

I. metallica Bosc (*I. robusta* Kröyer). Length 18 mm.; width 8 mm.; abdomen truncate: entire Atlantic coast; cosmopolitan; often on floating seaweed.

Fig. 599

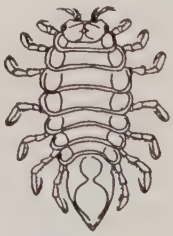

Fig. 600

Fig. 601

Fig. 599—*Chiridotea cæca* (Harger). Fig. 600—*Edotea triloba* (Harger). Fig. 601—*Erichsonella filiformis* (Harger).

2. Chiridotea Harger. Second antennae usually with a short flagellum, sides of head cleft at the eye and extending beyond it; first 3 pairs of legs prehensile, last 4 pairs ambulatory; abdomen composed of 4 segments: 2 species.

C. cæca (Say) (Fig. 599). Body ovate, with a long, pointed telson; length 8 mm.; width 4 mm.; antennae of nearly equal length; eyes small, dorsally placed: Florida to Nova Scotia; at the surface or in the sand.

3. **Edotea** Guérin. Second antennae of 4 to 6 segments and short; abdomen composed of a single segment; legs prehensile: 3 species.

E. triloba (Say) (Fig. 600). Length 7 mm.; width 3 mm.: New Jersey to Maine; under stones and decaying algae, in muddy places along the shore.

4. **Erichsonella** Benedict. First antennae short; second antennae long and composed of 6 segments; abdomen composed of a single segment; legs ambulatory: 3 American species.

E. filiformis (Say) (Fig. 601). Length 8 mm.; width 3 mm.: Atlantic coast, south to Cape Cod; in sand and among algae in shallow water.

Family 9. ASELLIDAE.

Body flattened, with 7 free thoracic segments, and with the abdominal segments forming a single, shield-like plate; abdominal appendages exclusively branchial and numbering 4 or 5 pairs; uropods terminal and biramose: principally fresh-water animals; 17 American species.

Key to the genera of *Asellidae* here described:

a_1 Eyes present.
  b_1 Last 6 pairs of legs uniunguiculate.....1. Asellus
  b_2 Last 6 pairs of legs biunguiculate.....2. Mancasellus
a_2 Eyes absent; cave-dwellers.....3. Cæcidotea

1. **Asellus** Geoffroy. Abdomen about as broad as long; legs uniunguiculate; mandible with a palp: 7 American species; in fresh water.

A. communis Say (Fig. 602). Length 15 mm.; breadth 5 mm.; first antennae short, second long; first pair of legs prehensile and subchelate, the others ambulatory, the last 3 being longer than the others: eastern United States; the commonest fresh-water isopod, occurring generally among vegetation.

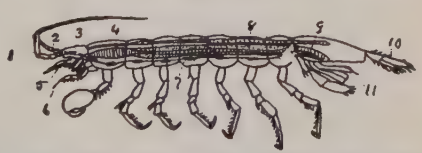

Fig. 602—Diagram of *Asellus communis*, showing the internal organs (McMurrich). 1, second antenna; 2, first antenna; 3, brain; 4, stomach; 5, mandible; 6, maxilliped; 7, nerve chord; 8, heart; 9, intestine; 10, uropod; 11, gills.

2. **Mancasellus** Harger. Abdomen about as broad as long; mandible without a palp; last 6 pairs of legs biunguiculate: 6 species; in fresh water.

M. macrourus Garman. Length 12 mm.; breadth 5 mm.; first pair of legs subchelate, the others ambulatory; side of the head cleft near the eye: central United States east of the Mississippi, often in caves.

3. **Cæcidotea** Packard. Body elongate and narrow; eyes wanting; abdomen much longer than broad: 4 species; in caves and similar places.

C. stygia Pack. Length 10 mm.; width 2 mm.; first pair of legs prehensile, the hand being armed with 2 long and 3 short teeth: central United States; in caves and deep wells.

Family 10. JANIRIDAE.

Body flattened and similar to the *Asellidae,* with the side of the head usually expanded under the eye; first pair of abdominal appendages in the female form a single large opercular plate, and in the male together with the second pair form a compound operculum: 20 American species; marine.

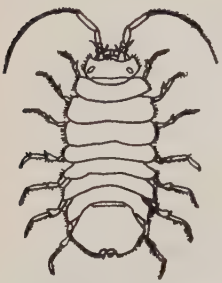

Fig. 603—*Jæra marina* (Harger).

1. Jæra Leach. First pair of antennae very small; uropods very small: 2 American species.

J. marina (Fabricius) (Fig. 603). Body oval, 5 mm. long, 2 mm. wide, and very variable in color, usually being mottled gray; legs ambulatory and triunguiculate: coast of New England; Europe; common between tide lines under stones and seaweeds.

2. Janira Leach. First pair of antennae and uropods well developed; side of head not expanded, or but slightly so: 5 American species.

J. alta (Stimpson) (Fig. 604). Length 7 mm.; width 2 mm.; legs biunguiculate: Atlantic coast from Nova Scotia to Virginia, from low-water mark to 500 fathoms.

Fig. 604—*Janira alta* (Harger).

Family 11. ONISCIDAE.

The sow bugs. Terrestrial isopods with an elliptical body, which is more or less flattened and cannot be rolled into a ball (except *Cylisticus convexus*); first antennae minute; second antennae long; thorax with 7 and abdomen with 6 free segments; legs ambulatory; 5 pairs of pleopods are respiratory plates, the second pair in the male terminating in a pair of long slender stylets; uropods long and terminal: common under logs, etc., and in other dark, damp places on the land; 200 species, 30 American.

Key to the genera of *Oniscidae* here described:

a_1 Antennae ending with 3 short segments forming the flagellum.
  b_1 Abdomen not abruptly narrower than thorax.....1. Oniscus
  b_2 Abdomen abruptly narrower than thorax.....2. Philoscia
a_2 Antennae ending with a flagellum of 2 short segments.
  b_1 Abdomen not abruptly narrower than thorax.
    c_1 Body convex, can be rolled into a ball.....3. Cylisticus
    c_2 Body flattened, cannot be rolled into a ball.....4. Porcellio
  b_2 Abdomen abruptly narrower than the thorax.....5. Metoponorthus

1. Oniscus L. Body broad, flattened, with a granulated or tuberculated surface; antennae ending with 3 short segments; side of head extended beneath the eyes: 1 species.

O. asellus L. (Fig. 605). Length 16 mm.; width 8 mm.; color deep slate, spotted with white, and white along the lateral edges: eastern and central states; Europe; common under bark of fallen trees, logs, stones, etc.

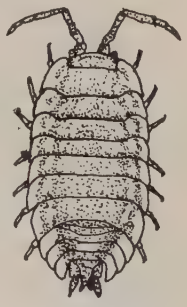

Fig. 605—*Oniscus asellus* (Paulmeier).

2. **Philoscia** Latreille. Second antennae ends with 3 short segments; side of head not extended under the eyes; abdomen abruptly narrower than the thorax: 7 American species.

P. vittata Say (Fig. 606). Length 8 mm.; width 4 mm.; color usually dark brown with 2 darker median stripes: along the seashore from New Jersey to Cape Cod, under stones and boards above high tide.

3. **Cylisticus** Schnitzler. Body rather elongate, smooth, very convex, and able to be rolled into a ball; head with lateral lobes; second antennae long, ending with 2 short segments; uropods long: 1 American species.

Fig. 606
Philoscia vittata (Harger).

C. convexus (DeGeer) (Fig. 607). Length 12 mm.; width 5 mm.; color brown or dark gray, spotted with white: eastern and central states; Europe; under logs and stones in rather dry places.

4. **Porcellio** Latreille. Body oval, flattened; head with lateral lobes; second antennae long, ending with 2 short segments; uropods long; respiratory plates of either the first 2 or all 5 pairs of pleopods provided with tracheae: 6 American species.

P. rathkei Brandt. Body granulate, 10 mm. long and 5 mm. wide, yellowish-brown in color with numerous black blotches and two lateral

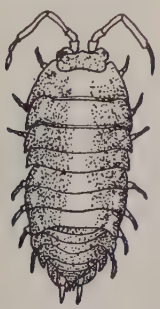

Fig. 607

Fig. 608

Fig. 609

Fig. 607—*Cylisticus convexus* (Paulmeier). Fig. 608—*Porcellio scaber* (Paulmeier). Fig. 609—*Metoponorthus pruinosus* (Paulmeier).

and usually a median light stripe: eastern and central states; Europe; common under boards, stones, etc.

P. scaber Lat. (Fig. 608). Body covered with minute tubercles, 12 mm. long, 7 mm. wide, of uniform black color, without spots or blotches: entire America; cosmopolitan; under bark, logs, etc.

P. lævis Lat. Body smooth or minutely granulate, 15 mm. long, 8 mm. wide, dark gray in color with 2 wavy median lighter bands: entire America; cosmopolitan.

5. **Metoponorthus** Budde-Lund. Body oval, flattened, without lateral lobes; second antennae long, ending in 2 short segments; abdomen abruptly narrower than thorax; uropods long: 4 American species.

M. pruinosus (Brandt) (Fig. 609). Length 9 mm.; width 4 mm.; color reddish-brown in the hinder and lateral portions, and lighter in the other portions: entire America; cosmopolitan; under logs, etc.

Family 12. ARMADILLIDIDAE.

Body convex and able to be rolled into a ball; first antennae minute; second antennae short; uropods short and not extending beyond the terminal segment: terrestrial; 6 genera and 23 American species.

Fig. 610—*Armadillidium vulgare* (Paulmeier).

Armadillidium Brandt. Pill bugs. With the characters of the family; exopodite of uropod large and lamellar; terminal segment triangular: 2 species.

A. vulgare (Latreille) (Fig. 610). Length 16 mm.; width 8 mm.; color black or dark gray with rows of indistinct spots: entire America; cosmopolitan: under stones, etc., in damp places.

Family 13. LIGYDIDAE.

Body elliptical or elongate; first antennae minute; second antennae long, with numerous small terminal segments; buccal mass prominent; uropods long: marine; 2 genera and 12 American species.

Fig. 611
Ligyda exotica (Richardson).

Ligyda Rafinesque. The two branches of the uropods of about equal length and styliform: 6 American species.

L. exotica (Roux) (Fig. 611). Body elongate, 48 mm. long (with uropods), 14 mm. wide: Florida to North Carolina; California; cosmopolitan; among rocks and on piles and docks; common.

L. oceanica (L.). Body oval, 22 mm. long (with uropods), 8 mm. wide, and with a granulate surface: New England; Europe.

Family 14. TRICHONISCIDAE.

Body elliptical, elongate; first antennae minute; second antennae ending with 3 or 5 small segments; abdomen not pointed behind, but truncate or indented; the 2 branches of each uropod of about the same length: 4 American species; terrestrial or in fresh water.

Trichoniscus Brandt. Head rounded in front; eyes small, composed each of 3 ocelli; second antennae long; abdomen abruptly narrower than thorax: 2 species.

T. pusillus Br. (Fig. 612). Length 3 mm.; width 1 mm.; body smooth: entire North America; Europe; under moss, in the woods.

Fig. 612 *Trichoniscus pusillus* (Richardson).

Family 15. BOPYRIDAE.

Parasites of decapods; male and female animals dissimilar, the female being asymmetrical and broad, and sometimes much deformed, the male more slender and symmetrical; antennae rudimentary; legs prehensile: 35 species, 29 American.

1. Probopyrus Giard and Bonnier. Segments of abdomen distinct in female, but fused, except at the edges, in the male; 5 pairs of abdominal appendages; uropods wanting: parasites in the gill chamber of decapods; 5 American species.

P. pandalicola (Packard). Body (of female) 5 mm. long, white in color with black markings; the female lies against the body of the host, the ventral side of the thorax having the brood pouch with the eggs, the much smaller male is usually found clinging to the female: entire Atlantic coast, on *Palæmonetes,* producing large tumors under the carapace.

2. Phryxus Rathke. Body of female very asymmetrical, one side being greatly swollen; 5 abdominal segments; the legs of the longer side of the body wanting, except on the first thoracic segment, on the shorter side very small; antennae and uropods rudimentary; abdomen of male composed of a single triangular segment, without appendages: parasitic on the abdomen of decapods; 1 species.

P. abdominalis (Kröyer). Body of female 9 mm. long, 7 mm. wide; of male 3 mm. long and 1 mm. wide: circumpolar, extending to Vineyard and Puget Sounds; on the abdomen of *Pandalus* and other prawns.

3. Bopyroides Stimpson. Body of female somewhat asymmetrical, with 6 abdominal segments and 7 pairs of legs, without abdominal appendages; abdomen of male forming a single piece without appendages; antennae rudimentary: 1 species.

B. hippolytes Kröyer. Body of female 8 mm. long and 7 mm. wide; of male 3 mm. long and 1 mm. wide: circumpolar, extending to Boston and to Puget Sound; on the gills of *Pandalus* and other prawns.

Division 3. THORACOSTRACA.*

Malacostraca often of large size in which 3 or more of the thoracic somites are fused with the head, and the cephalothorax thus formed is covered with a carapace; projecting forwards from the anterior end of the carapace in most species is the spike-like rostrum; eyes at the end of movable stalks or peduncles (except in the *Cumacea*); the sixth pair of pleopods (uropods) together with the last body segment (telson) forms, except in the case of the crabs, a swimming fin, by striking which vigorously beneath the body the animal propels itself rapidly backwards; the eggs and sometimes the young usually carried beneath the abdomen attached to the pleopods, the young in most forms passing through a metamorphosis before attaining the form of the parents: 4 orders.

Key to the orders of *Thoracostraca:*

a_1 Carapace does not cover the entire thorax.
  b_1 Thoracic appendages all biramose.....1. Schizopoda
  b_2 Thoracic appendages not all biramose.
    c_1 Abdomen large and wider than the small cephalothorax...2. Stomatopoda
    c_2 Abdomen narrow.....3. Cumacea
a_2 Carapace covers the entire thorax.....4. Decapoda

Order 1. SCHIZOPODA.

Body elongate and usually more or less transparent and with a thin carapace which covers nearly all of the thorax; the 8 thoracic feet may all support gills and are biramose, the anterior 2 pairs being slightly modified to form maxillipeds; eggs carried beneath the thorax as in the *Arthrostraca;* young born in some species as nauplii: 3 families and about 300 species, mostly marine; 11 American species.

Family MYSIDAE.

No gills present; first 2 pairs of thoracic appendages (maxillipeds) shorter than the following 6; abdominal appendages often rudimentary in female; the endopodites of the uropods bear each an auditory sac; 2 to 7 pairs of marsupial plates beneath the thorax within which the young develop: 21 genera and 90 species, mostly marine.

1. **Mysis** Latreille. Body laterally compressed; fourth pair of abdominal appendages in male are long stilets; antennal scale long: often in swarms in the North Atlantic; 23 species, 4 American, 1 in fresh water.

* See "The Stalk-eyed Crustaceans of the Atlantic Coast," etc., by S. I. Smith, Trans. Conn. Acad., Vol. 5, p. 27.

M. stenolepis S. I. Smith (Fig. 613). Body cylindrical; carapace with a short, blunt rostrum, and with its lower anterior margin extended to form a sharp tooth; body bends between the first and second abdominal segments; length, male, 23 mm., female, 30 mm.; color white, with black stellate spots: coast of New England and southwards, often common in eel grass.

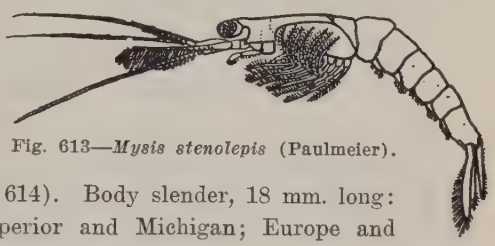

Fig. 613—*Mysis stenolepis* (Paulmeier).

M. relicta Lovén (Fig. 614). Body slender, 18 mm. long: in Lakes Superior and Michigan; Europe and Asia, in large fresh-water lakes.

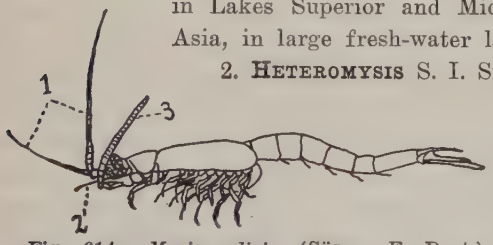

Fig. 614 — *Mysis relicta* (Süssw. F. Deut.). 1, flagella of first antenna; 2, scale of second antenna; 3, second antenna.

2. **Heteromysis** S. I. Smith. First pair of thoracic legs larger than the others and ending each with a claw; antennal scale very small; abdominal appendages rudimentary in both male and female: one species.

H. formosa Smith. Length of male 6 mm., of female 8.5 mm.; females rose-colored; males colorless: coast of New England, in eel grass or often in dead mollusk shells, sometimes in swarms.

Order 2. STOMATOPODA.*

Body large, with a small flat carapace which does not cover the posterior thoracic somites, with a broad elongated abdomen bearing gills on the appendages; 5 pairs of maxillipeds, the second pair being much larger than the rest and subchelate, and 3 pairs of periopods; heart long and tubular; liver, testes, and ovaries extending the length of the thorax and abdomen, the testes being a pair of delicate tubes and the ovaries a broad median band: 10 genera and about 90 species, all marine; often used for food.

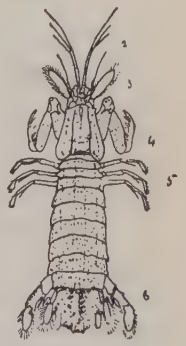

Fig. 615—*Squilla empusa* (Paulmeier). 1, first antenna; 2, second antenna; 3, scale of second antenna; 4, second maxilliped; 5, periopods; 6, uropod.

Squilla Fabricius. Five posterior thoracic somites not covered by the carapace, of which the first is very small and the second has a lateral spur on each side and the last 3 bear the periopods: 21 species.

* See "Report on the Crustacea of the Order Stomatopoda," etc., by R. P. Biglow, Proc. U. S. N. Mus., Vol. 17, p. 489, 1891.

S. empusa Say (Fig. 615). First antennae with 3 flagella; second shorter and with a very large flat scale (exopodite); length up to 25 cm.; color greenish-gray: Florida to Cape Cod, in shallow burrows in the mud, between tide lines and in shallow water, each burrow usually having 2 or 3 openings a few feet apart; often very common.

Order 3. CUMACEA.

Body small, with a small carapace which does not cover the hinder 4 or 5 thoracic somites, and with a long slender abdomen; first antennae short; second antennae short in the female and long in the male; mandibles without palp; 2 pairs of maxillipeds and 6 pairs of periopods present, 2 to 5 pairs of the latter being biramose (small exopodite present); the pleopods, with the exception of the uropods, wanting in the female, while in the male 2 to 5 pleopods may be present; a single pair of gills on the first pair of maxillipeds; eyes close together and sessile or wanting; the large eggs are carried by the female in a brood pouch under the foremost free thoracic segments and the hinder part of the carapace; the young animals are like the parents in appearance, but are without the last pair of thoracic and all the abdominal legs when born: 9 families and about 300 species, all marine and living mostly in the sand and mud.

Family DIASTYLIDAE.

With the characters given above: 8 American genera.

Diastylis Say. Seven abdominal segments present, the telson being well developed and long and pointed; a single eye or none; the 3 anterior pairs of periopods in the female and the 5 in the male biramose: numerous species, several American.

Fig. 616—*Diastylis quadrispinosa* (Verrill).

D. quadrispinosa G. O. Sars (Fig. 616). Length 10 mm.; body flesh color or brownish; a short spine projects from the carapace on each side a little behind the large triangular rostrum: Nova Scotia to New Jersey in 2 to 200 fathoms; often very common.

Order 4. DECAPODA.

Shrimps, crayfish, lobsters, and crabs. Thoracostracans in which the carapace covers the entire thorax, the cephalothorax being cylindrical in the *Macrura* and broad and more or less flattened in the *Brachyura;* gills on the thorax, extending either from the legs (podobranchs), the joints (arthrobranchs), or the body wall (pleurobranchs) and situated in the gill chamber on each side of the body (Fig. 623); abdomen well

developed in the former group and small and bent under the cephalothorax in the latter; 3 pairs of maxillipeds and 5 pairs of periopods present; first pair of periopods (chelipeds) usually much larger than the others and chelate, forming the pinching claws (chelae); other periopods also often chelate; eggs and sometimes the young carried on the pleopods: about 6,000 species, mostly marine; the crayfish, certain crabs, and a few others being fresh-water or terrestrial animals; 2 suborders.

Key to the suborders of *Decapoda:*

a_1 Body more or less cylindrical and elongate; antennae long; tail fin usually present ..... 1. MACRURA

a_2 Cephalothorax short and broad, with the abdomen bent under it; crabs. 2. BRACHYURA

SUBORDER 1. MACRURA.*

Body more or less cylindrical and elongate with a well-developed abdomen, at the hinder end of which is usually a swimming fin formed of the sixth pair of pleopods (uropods) and the telson; antennae well developed and usually long, the first antenna having 2 or more flagella, the second usually with an antennal scale; the young are born as nauplii in *Peneus* and *Lucifer,* but in most other forms in a more advanced larval stage: about 10 American families grouped in 4 tribes.

Key to the tribes of *Macrura:*

a_1 Last pair of thoracic feet normal; swimming fin present.

b_1 Shrimps and prawns; body rather small and transparent; antennal scale large (Fig. 617) ..... 1. CARIDEA

b_2 Burrowing marine animals of moderate size; antennal scale usually absent ..... 2. THALASSINIDEA

b_3 Crayfish and lobsters; body of moderate or large size, with small antennal scale, or none ..... 3. ASTACIDEA

a_2 Last pair of thoracic feet reduced and projecting upwards; no swimming fin; hermit crabs, etc ..... 4. ANOMURA

TRIBE 1. CARIDEA.† (MACRURA NATANTIA.)

Shrimps and prawns. Small forms with a compressed and more or less transparent body; carapace smooth, without sutures and with a long rostrum; antennal scale large; thoracic legs usually long and delicate: about 17 families and several hundred species.

Key to the families of *Caridea* here described:

a_1 First 3 pairs of periopods not all chelate.

b_1 Second pair of periopods only chelate; first pair very stout and subchelate ..... 1. CRANGONIDAE

b_2 First 2 pairs of periopods usually chelate; first antennae with 3 flagella. 2. PALÆMONIDAE

a_2 First 3 pairs of periopods chelate ..... 3. PENEIDAE

* See "Embryology and Metamorphosis of the Macroura," by W. K. Brooks and F. H. Herrick, Mem. Nat. Acad. Sci., Vol. 5, 1892.

† See "Synopsis of the Caridea of North America," by J. S. Kingsley, Am. Nat., Vol. 33, p. 709, 1899.

Family 1. CRANGONIDAE.

Shrimps. Second antennae long, with a large antennal scale; first pair of periopods much stouter than the others and subchelate; second pair of periopods small and chelate; mandibles slender, not bifid or expanded at the tip and without a palp: marine; about 10 American genera.

Fig. 617—*Crangon vulgaris* (Leunis). 1, first antenna; 2, first periopod; 3, antennal scale; 4, second antenna.

Crangon Fabricius. Cephalothorax somewhat depressed; rostrum short; first antennae with 2 flagella: 15 species, about 8 American.

C. vulgaris Fabr. The edible shrimp (Fig. 617). Length 5 cm.; color light, with dark markings: Labrador to South Carolina; Europe; Pacific coast; common at the bottom of sandy bays, in shallow water, often buried in the sand.

C. boreas (Phipps). Three median dorsal spines on cephalothorax: Atlantic coast as far south as Cape Cod; North Pacific coast.

C. franciscorum Stimpson. The California shrimp. Length 7 cm.; posterior margin of fifth abdominal segment with a spine on each side; movable finger of cheliped long and parallel with the hand: common at San Francisco.

Family 2. PALÆMONIDAE.

Prawns and shrimps. Second antennae long, with a large antennal scale; first antennae with 3 flagella; third maxillipeds foot-like; mandibles with a bifid tip; rostrum long and usually serrate: mostly marine; about 12 American genera.

Key to the genera of *Palæmonidae* here described:

a_1 Right and left claws of the first pair of periopods of the same size.
  b_1 First pair of periopods shorter but not thicker than the second.
    c_1 First 2 pairs of periopods chelate.
      d_1 Mandibular palp absent.....1. Palæmonetes
      d_2 Mandibular palp present.....2. Palæmon
    c_2 First pair of periopods not chelate.....3. Pandalus
  b_2 First pair of periopods thicker than the second; abdomen bent down at the third segment.
    c_1 Mandibular palp present.....4. Hippolyte
    c_2 Mandibular palp absent.....5. Virbius
a_2 Right and left claws of the first pair of periopods of different size..6. Alpheus

1. **Palæmonetes** Heller. Mandibles without palp; first 2 pairs of periopods chelate, the first pair being smaller than the second: about 6 species, 3 American, in salt, brackish, and fresh water.

P. vulgaris (Say). Common prawn (Fig. 618). Rostrum long, straight and serrate; length 45 mm.; body translucent, with brownish spots: Massachusetts to Florida; common on rock weed, and eel grass on muddy bottoms, often where the water is brackish or fresh.

P. paludosa (Gibbes). Length 35 mm.; rostrum serrate below as well as above: in fresh-water lakes and streams in eastern North America (Lake Erie, etc.).

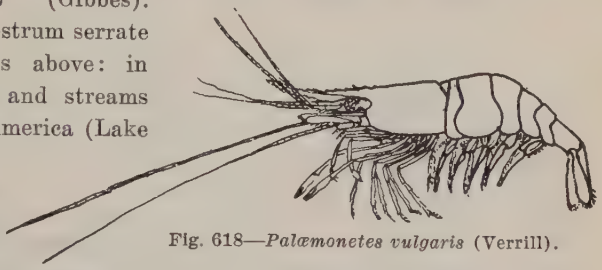

Fig. 618—*Palæmonetes vulgaris* (Verrill).

2. Palæmon Fabricius. Like Palæmonetes but with a 3-jointed mandibulary palp (Fig. 619): about 70 species, 3 American; in salt and fresh water.

P. ohionis S. I. Smith. Length 6 cm.; carapace about a quarter the length of the body, with a lateral spine on each side: Ohio and Mississippi Rivers; often used for food.

Fig. 619—Mandible of *Palæmon*, showing palp (Smith).

3. Pandalus Leach. Deep-water prawns. First and second pairs of periopods slender, the first not chelate, the second chelate: 10 American species.

P. montagui Leach. Length 10 cm.; body with transverse red stripes; appendages thickly spotted with red: Chesapeake Bay to Greenland; Europe; in 10 to 100 fathoms.

4. Hippolyte Leach. First 2 pairs of periopods chelate, the first pair shorter and thicker than the second; abdomen sharply bent down at third segment; mandibular palp present: numerous species, about 30 American.

H. pusiola Kröyer. Length 25 mm.; pale gray or flesh color, brightly spotted with red, usually with a mid-dorsal white stripe, and sometimes with transverse bands of red and white: often common on rocky bottoms in shallow water from Vineyard Sound to Greenland; Europe.

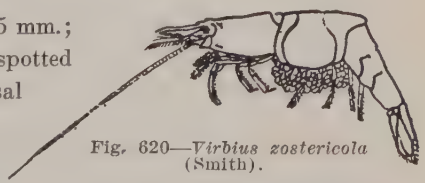

Fig. 620—*Virbius zostericola* (Smith).

5. Virbius Stimpson. Similar to *Hippolyte* but without a mandibular palp: many species, 2 American.

V. zostericola S. I. Smith (Fig. 620). Rostrum straight and as long as the carapace, the latter being smooth and with 3 spines on an-

terior part; abdomen sharply bent at the third segment; length 15 to 26 mm.; color translucent, usually greenish and spotted with red: Vineyard Sound and southwards, common in eel grass.

6. **Alpheus** Fabricius. First pair of periopods larger than the others and chelate, the right and left claws of the first pair being thick and of very unequal size; rostrum small or absent; abdomen not sharply bent; eye stalks short and hidden: about one hundred species, twelve American, living principally along our southern coasts.

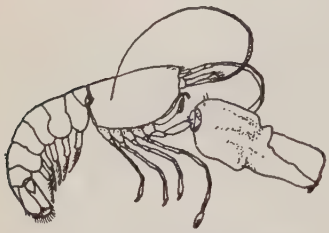

Fig. 621—*Alpheus heterochelis* (Kingsley).

A. minus Say. Rostrum present; hinder feet with spines beneath; length 4 cm.: Atlantic coast from New Jersey to Florida; southern Californian coast.

A. heterochelis Say (Fig. 621). Large claw with a constriction at its middle; rostrum spiniform; length 5 cm.: Virginia to Florida; California.

Family 3. PENEIDAE.

Southern shrimps and prawns. First 3 pairs of periopods chelate, the third pair being the largest; rostrum long; second antennae long, with a large scale; abdomen compressed and not bent sharply: about 2 American genera, marine, inhabiting chiefly the tropics and the deep sea.

Peneus Latreille. Rostrum serrate; eye stalks jointed; the young born as nauplii: 3 American species.

P. setiferus (L.). A lateral groove on each side of the forward half of the carapace; flagella of first antennae very short; length up to 16 cm.: common in shallow water along the coast from Virginia southwards, where it is an article of food, the larger individuals being known in the market as prawns and the smaller as shrimps.

P. brasiliensis Latreille. Like *P. setiferus,* but with the lateral grooves extending the length of the carapace: Atlantic coast north to Cape Cod, occurring with *P. setiferus.*

Tribe 2. THALASSINIDEA.*

Animals of moderate size, with a cylindrical or flattened and translucent body and a large abdomen; carapace with 2 longitudinal sutures; antennal scale usually wanting; first pair of periopods form pinching claws of unequal size: marine, burrowing animals; 3 families and about 75 species.

* See "Synopsis of Astacoid and Thalassinoid Crustacea," by J. S. Kingsley, Am. Nat., Vol. 33, p. 819, 1899.

Family CALLIANASSIDAE.

With the characters given above: about 7 American genera.

1. Callianassa Leach. Cuticula soft and smooth; first 2 pairs of periopods chelate, the first pair being large and very unequal in size; eye stalks flattened; third pair of maxillipeds flattened: about 20 species, 6 American.

C. stimpsoni S. I. Smith. Length 6 cm.; small cheliped about half as long as the large one; carapace smooth and glossy: from Long Island Sound southwards, in burrows in the mud between tide lines and in shallow water.

Fig. 622—*Gebia affinis* (Verrill).

2. Gebia Leach. Cuticula soft and smooth; forward portion of cephalothorax compressed, with a triangular, hairy rostrum; second pair of periopods not chelate; third pair of maxillipeds pediform: 10 species, 2 American.

G. affinis Say (Fig. 622). Length 10 cm.: Long Island Sound to South Carolina, living in burrows in the mud between tide lines and in shallow water.

Tribe 3. ASTACIDEA.

Lobsters and crayfish (Sig. 623). Body of moderate or large size and with a thick shell; first antennae with 2 flagella, second either with a scale or with none and much longer than the first; no longitudinal sutures, but usually a transverse cervical suture in the carapace: 4 families and about 150 species.

Key to the families of *Astacidea* here described:

a_1 Antennal scale and cheliped present.
b_1 Animals marine.....1. Nephropsidae
b_2 Animals in fresh water.....2. Astacidae
a_2 Antennal scale and cheliped absent.....3. Palinuridae

Family 1. NEPHROPSIDAE.

Lobsters. Body of large size; rostrum dentate along the lateral margins; first 3 pairs of periopods chelate, the first pair very large, forming the pinching claws: 3 genera.

Homarus Milne-Edwards. Rostrum with 3 teeth on each side; second antennae with a small scale; eyes round: 2 species.

H. americanus* M.-Ed. American lobster. Length up to 60 cm.; greatest weight 13 kg. or over 28 pounds; length of the average adult lobster 25 cm.; average weight less than a kg. or about one and three-quarters or two pounds; color usually dark green with darker spots and

* See "The American Lobster," etc., by F. H. Herrick, Bull. U. S. Fish. Com. for 1895. "Natural History of the American Lobster," by same, Bull. Bureau Fish., Vol. 29, p. 149, 1909.

yellowish underneath: Atlantic coast from Labrador to North Carolina, in shallow water in summer and in deeper water in winter. Lobsters are caught mostly off the coast of Canada and the New England states and are our most important food crustacean. The annual catch has amounted to over 100,000,000 in some years but is now much less.

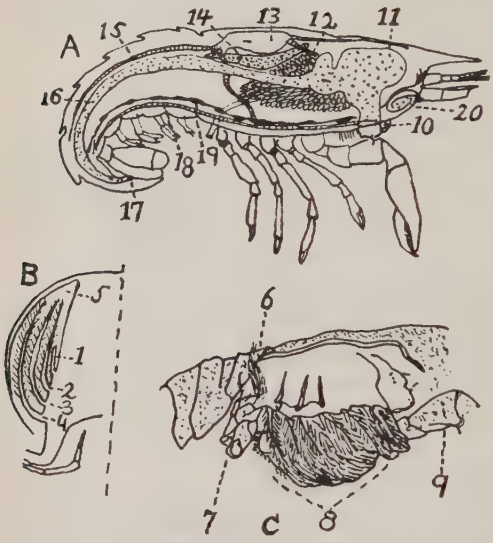

Fig. 623—A, diagram of a crayfish showing arrangement of internal organs (McMurrich); B, diagram of cross section of the cephalothorax showing gill chamber; C, interior of gill chamber of *Astacus*, the outer wall having been removed (Süssw. F. Deut.). 1, pleurobranch; 2, upper arthobranch; 3, lower arthrobranch; 4, podobranch; 5, gill chamber; 6, pleurobranch of the last thoracic somite; 7, last periopod; 8, gills; 9, first periopod; 10, mouth; 11, stomach; 12, liver; 13, heart; 14, gonad; 15, dorsal artery; 16, intestine; 17, anus; 18, ventral artery; 19, nerve chord; 20, kidney.

FAMILY 2. ASTACIDAE.*

Crayfish. Body not so large as in previous family; rostrum without lateral teeth: several genera and over 100 species; in fresh water.

Key to the genera of *Astacidae* here described:

a_1 Pacific slope crayfish. 1. ASTACUS

a_2 Atlantic slope and Mississippi valley crayfish. 2. CAMBARUS

1. ASTACUS Fabricius. A pair of gills (pleurobranchs) on the last thoracic somite (Fig. 623, C, 6), and 18 pairs in all: about 15 species, 5 on the Pacific slope, the remainder in Europe and Asia.

A. nigrescens Stimpson. Chelae naked on outer face; margins of rostrum denticulate; length 10 cm.; color dark greenish: San Francisco to Alaska, near the coast; used for food.

2. **CAMBARUS**† Erichson. Common American crayfish (Fig. 623).

* See "Monograph of the North American Astacidae," by H. A. Hagen, Mem. Mus. Comp. Zool., Vol. 3, 1870. "The Crayfish," by T. H. Huxley, 1881. "A Revision of the Astacidae," by W. Faxon, Mem. Mus. Comp. Zool., Vol. 10, 1885. "Observations on the Astacidae," etc., by W. Faxon, Proc. U. S. Nat. Mus., Vol. 20, p. 643, 1898. "Synopsis of the Astacidae of North America," by W. P. Hay, Am. Nat., Vol. 33, p. 957, 1899. "The Young of the Crayfish Astacus and Cambarus," by E. A. Andrews, Smithsonian Contributions to Knowledge, Vol. 35, p. 1, 1907.

† See "Ecological Catalogue of the Crayfishes Belonging to the Genus Cambarus," by J. Arthur Harris, Kansas Univ. Sci. Bull., Vol. 2, p. 51, 1903. "The Crawfishes of the State of Pennsylvania," by A. E. Ortmann, Memoirs of the Carnegie Museum, Vol. 2, p. 343, 1906. "Breeding Habits of the Crayfish," by E. A. Andrews, Am. Nat., Vol. 38, p. 165, 1904.

No gills on the last thoracic somite and 17 pairs in all; first pair of swimmerets bifid and often hooked at the apex in the male: about 70 species, all in North America and east of the Rocky Mountains. The animals live in streams, lakes, and swamps, resting under stones or in burrows or among aquatic vegetation near the surface; a few species are terrestrial, living in burrows. Crayfishes are omnivorous feeders, eating decaying animal and plant substances, but also living animals and plants. Spawning occurs in the springtime and pairing in the fall in the case of *C. diogenes* and *C. limosus* and others, but *C. bartoni* and others probably pair and spawn the year round. The eggs are carried by the mother attached to her abdominal legs until they hatch; the young animals when born have the form of the parents and live for a while with the mother, holding on to her abdominal legs with their claws. Crayfishes are used for food in New York and other large cities.

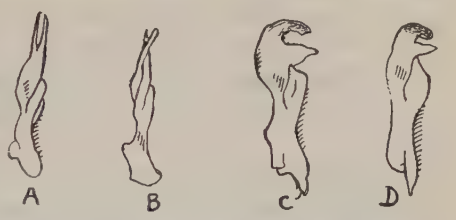

Fig. 624—The anterior abdominal appendage (male) in *Cambarus* (Ortmann). A, *C. propinquus;* B, *C. limosus;* C, *C. bartoni;* D, *C. diogenes.*

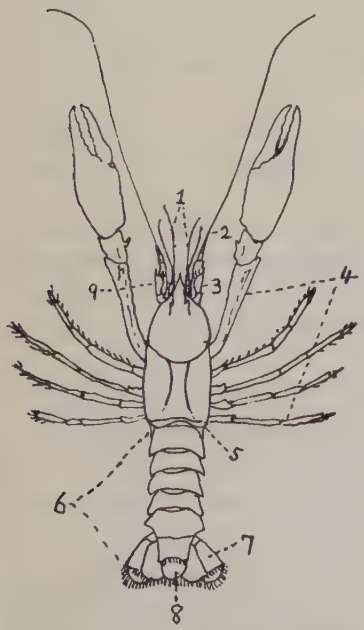

Fig. 625 — *Cambarus pellucidus* (Kingsley). 1, first antenna; 2, second antenna; 3, antennal scale; 4, periopods; 5, carapace; 6, abdomen; 7, uropod; 8, telson; 9, rostrum.

C. bartoni* (Fabricius) (Fig. 624, C). First pair of abdominal appendages of the male terminated with 2 strongly recurved tips; length 8 cm.; the eastern specimens have a short quadrangular rostrum; in the western specimens the rostrum tends to be elongate; body with few or no hairs; carapace depressed: North America, almost to the Mississippi, but especially along the Atlantic slope, usually in clear, small streams, but also occasionally in muddy ones where it may burrow; one of our most widely distributed and commonest crayfish.

* See "Notes on the Habits of Certain Crayfish," by C. C. Abbott, Am. Nat., Vol. 7, p. 80, 1873.

C. limosus (Rafinesque) (*C. affinis* Say) (Fig. 624, B). First pair of abdominal appendages of the male terminated with 2 short, straight, divergent tips; length 10 cm.; body hairy all over; sides of carapace spiny; rostrum broad with parallel sides: eastern North America, not west of the Alleghenies; common in the larger rivers, usually does not burrow; the crayfish which is most commonly sent to the New York markets.

C. pellucidus (Tellkampf) (Fig. 625). First pair of abdominal appendages clavate, the outer part being truncate and toothed; eyes atrophied; length 9 cm.: in caves in Indiana and Kentucky.

C. diogenes Girard (Fig. 624, D). First pair of abdominal appendages in male terminate with 2 strongly recurved tips; rostrum rather slender; length 8 cm.: widely distributed and often common in the entire country east of the Rocky Mountains; preëminently a burrowing species, being found in swamps and meadows often far from a stream; the burrows are from 1 to 3 feet deep, with an enlargement at the bottom filled with water; often with a chimney to the height of several inches over the top.

C. virilis Hagen. First pair of abdominal appendages in male acute, tapering, divergent; length 8 cm.: common in central states, in large rivers and lakes.

C. propinquus Girard (Fig. 624, A). First pair of abdominal appendages in male terminating in 2 elongate straight convergent tips; length 7 cm.; rostrum with a median ridge: common throughout the central part of the country, especially in large rivers and lakes.

Family 3. PALINURIDAE.

Spiny lobsters. Body of large size; antennal scale absent; none of the periopods chelate: several genera.

Panulirus Gray. Rostrum absent; flagella of antennae long: several species.

P. argus (Latreille). Florida crayfish. First pair of antennae with a very long basal joint; body 20 to 40 cm. long; color violet, red, and brown: common on coral reefs off the Florida coast; an important article of food.

Tribe 4. ANOMURA.

Last pair of thoracic legs reduced in size and extend backwards and upwards; a swimming fin usually not developed: 2 families, both marine.

Key to the families of *Anomura:*

a_1 Animals burrow in the sand.....1. Hippidae
a_2 Animals live in snail shells; hermit crabs.....2. Paguridae

Family 1. HIPPIDAE.

Cephalothorax cylindrical, with the abdomen bent under it; telson triangular and elongate; first pair of periopods not chelate: 3 genera and about 20 species, which burrow in the sand.

Hippa Fabricius. Second antennae long and fringed, with long hairs on its hinder surface; eye stalk very long: 2 species, 1 American.

H. talpoida Say. The sand bug (Fig. 626). Length 25 mm.; color whitish tinged with purple on the back: Cape Cod to Florida; Pacific coast; very common on sand bottoms and beaches, in which it burrows with great rapidity.

Fig. 626
Hippa talpoida (Verrill).

Family 2. PAGURIDAE.

Hermit crabs. Cephalothorax flattened, and with a hard shell; abdomen usually asymmetrical, elongate, and soft; eye stalks long; first pair of periopods large and chelate, last pair reduced in size and extending backwards and upwards, abdominal appendages rudimentary or wanting, the last pair used to hold the animal in the snail shell in which it lives. Allied to the hermit crabs is one of the most remarkable terrestrial decopod crustaceans, *Birgus latro,* the palm crab of the Pacific. It lives in holes in the ground and seldom goes into the water, but breathes air, the gill chambers being converted by the presence of a network of blood capillaries into lungs, while the gills are very small. Its food consists of cocoanuts, which, however, it does not climb the trees to get, as it is popularly supposed to do. The family contains about 20 genera.

Fig. 627—*Pagurus pollicaris,* out of its shell (Paulmeier).

Pagurus Fabricius. First pair of antennae short, second pair long; right claw usually the larger: the animal lives in the empty shell of some marine snail which it carries about with it, and as it increases in size changes for a larger one; the shell is frequently more or less covered with colonies of a hydroid, *Hydractinia echinata,* with which it lives in commensalism, the hydroid enlarging the shell by building up its free edge and thus saving the crab the necessity of changing its abode; over 100 species.

P. longicarpus Say. Small hermit crab. Chelae smooth and elongate: very common from Maine to South Carolina, usually inhabiting the shells of small snails in rock pools and shallow water along the beach.

P. pollicaris Say (Fig. 627). Large or warty hermit crab. Chelae covered with tubercles, and very wide and stout, and used by the animal to close the opening of the shell: Maine to Florida, usually inhabiting the shells of *Fulgur, Natica,* or other large snails in deeper water along the shores.

Suborder 2. BRACHYURA.

Crabs. Cephalothorax short and broad, with the small abdomen bent under it; abdomen of the male very narrow, with rudimentary legs and fitting into a groove of the ventral surface of the cephalothorax; abdomen of the female broad, with 4 pairs of well-developed biramose legs to which the eggs are attached; antennae very short and often foot-like; third pair of maxillipeds flat and plate-like and covering the other mouth parts; the 5 pairs of periopods well developed, the first pair forming the large pinching claws; the abdominal legs much reduced, from 1 to 4 pairs being present; no uropods present; young usually born in the zoœa stage and pass through the megalopa stage before reaching maturity (Fig. 628).

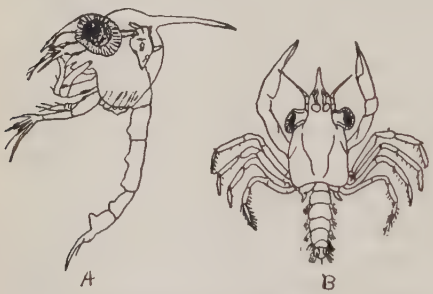

Fig. 628—Larvae of crab (Claus). A, zoœa; B, megalopa.

The crabs are the highest crustaceans. They occur mostly in the sea, living on or near the bottom, from tide lines to very great depths. Some, however, like the blue crab, swim very well and rapidly and are frequently seen near the surface. Some species, like the fiddler crabs and the sand crabs, live near the high-water line or above it and have become to a greater or less degree terrestrial animals. They run about rapidly over the sand, in which they dig deep burrows, and their gills and gill chamber are especially adapted to the absorption and retention of moisture from the damp sand. Still other crabs, as those belonging to the *Gecarcinidae,* the land crabs which are often distinguished by their large size, are found habitually far from the water, to which they return periodically to deposit their eggs. *Cardisoma guanhumi,* the common land crab of the West Indies and Bermuda, occasionally makes its appearance in Texas. The crabs of the family *Thelphusidae* live exclusively in fresh water, the best-known representative being *Thelphusa fluviatilis,* the common fresh-water crab of southern Europe. The suborder contains 4 divisions.

Key to the divisions of *Brachyura* here described:

a_1 Carapace more or less triangular, being narrow in front....1. Oxyrhyncha
a_2 Carapace more or less circular, elliptical or rectangular, with a wide-arched or straight front margin.
b_1 Carapace elliptical, with an arched front.....2. Cyclometopa
b_2 Carapace rectangular, with a straight front margin.....3. Catometopa

Division 1. OXYRHYNCHA.*

Carapace usually narrow and triangular in front and broad and rounded behind; 9 pairs of gills; first antennae longitudinally folded: 3 families.

Family MAIIDAE.

Carapace narrow in front, rounded and broad in the middle, tapering anteriorly to the prominent rostrum, which may be bifurcate: about 34 American genera, all marine and littoral and occurring principally in southern waters; some of the species have the habit of concealing themselves by placing on their backs with their pincers, algae, sponges, etc., which often grow there.

1. **Libinia** Leach. Spider crabs. Eyes can be retracted into orbits, which conceal them; rostrum bifurcate; body covered with a dense growth of chitinous hairs which give it a furry appearance; it may also have growing on it hydroids, algae, worm tubes, etc., which tend to conceal it: 6 species.

L. emarginata† Leach (Fig. 629). Carapace evenly rounded behind and with spines on the back, 9 of these being median in position; legs long, the chelipeds in the male being very long; length of carapace 7 cm.; breadth 6 cm.: Atlantic coast from Maine to Florida, very common on mud flats and oyster beds.

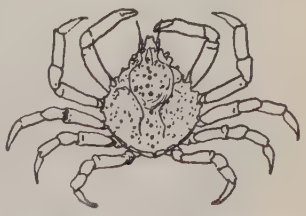

Fig. 629—*Libinia emarginata* (Rathbun).

L. dubia Milne-Edwards. Like the above, but with fewer spines on the back, 6 of which are median: Cape Cod to Florida; less common than *L. emarginata.*

2. **Hyas** Leach. Carapace more or less triangular; rostrum bifurcate, the 2 branches converging, eyes in orbits but not completely concealed: 3 species.

H. coarctatus Leach. Toad crab. Lateral edges of carapace dilated

* See "Catalogue of the Crabs," etc., by Mary J. Rathbun, Proc. U. S. Nat. Mus., Vol. 15, p. 231, 1892; also Proc. U. S. Nat. Mus., Vol. 16, p. 63, 1893. "Synopsis of the Oxyrhynchous and Oxystomatous Crabs of North America," by Mary J. Rathbun, Am. Nat., Vol. 34, 1900.

† See "On the Anatomy of Libinia emarginata," by E. A. Andrews, Trans. Conn. Acad., Vol. 6, p. 99, 1884.

anteriorly; length of carapace 8 cm.; width 6.4 cm.: Greenland to Virginia; Europe; North Pacific; in 5 to 1,000 fathoms.

3. **Pelia** Bell. Carapace triangular, and much longer than broad; surface smooth; eye stalk in an orbit but not completely concealed: 2 American species.

P. mutica (Gibbes). Small spider crabs. Claw of male with nearly parallel sides and with edges which meet only at the tip: Cape Cod to Florida and the Gulf of Mexico, from low-water mark to 15 fathoms.

Division 2. CYCLOMETOPA.*

Carapace more or less circular or elliptical in form and usually broader than long, the front forming a regular arch, and without a distinct rostrum; 9 pairs of gills present: 6 families.

Key to the families of *Cyclometopa* here described:

a_1 First antennae folded longitudinally or nearly so.....1. Cancridae
a_2 First antennae folded transversely or obliquely.
b_1 Last pair of legs not flattened for swimming.....2. Pilumnidae
b_2 Last pair of legs flattened for swimming.....3. Portunidae

Family 1. CANCRIDAE.

Carapace usually broader than long and with very short rostrum or none at all; anterior margin arched and serrate; last pair of legs pointed at the end: about 4 genera.

Cancer L. Carapace flattened, and more or less elliptical in shape; the outer maxillipeds completely cover the other mouth parts: 11 American species, 2 on the Atlantic coast.

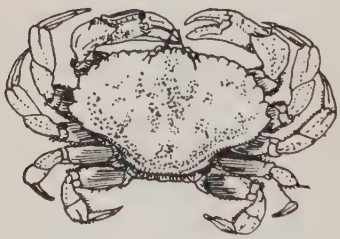

Fig. 630—*Cancer irroratus* (Rathbun).

C. irroratus Say. Rock crab (Fig. 630). Anterior margin of carapace with 9 blunt teeth on each side; length of carapace 7 cm.; breadth 10 cm.; color yellowish, thickly spotted with small reddish dots: Labrador to South Carolina; common among rocks and in the sand, in which it may lie buried, from low water to 300 fathoms; the commonest crab on the New England coast, where it is occasionally used for food.

C. borealis Stimpson. The northern or Jonah crab. Similar to the preceding but larger, with a more convex and much rougher carapace; color brick red: Labrador to Connecticut, often common among the rocks in exposed places, not living under the rocks or in the sandy or muddy bays.

* See "Synopsis of the Cyclometopous or Cancroid Crabs of North America," by Mary J. Rathbun, Am. Nat., Vol. 34, 1900.

C. magister Dana. The edible crab of California. Carapace 12 cm. long and 15 cm. wide, with 9 short spines on each side of the anterior margin; color reddish-brown: common below low-water mark on the entire Pacific coast, where it is used for food.

Family 2. PILUMNIDAE.

Small dull-colored crabs with the first antennae folded transversely or obliquely, with a nearly round cephalothorax and without swimming periopods: about 15 American genera, mostly southern.

Panopeus* Milne-Edwards. Mud crabs. Carapace slightly broader than long: small, inconspicuous crabs which live on muddy bottoms along the shore, often on oyster beds in brackish water, or even in fresh water; about 14 American species.

P. (*Neopanopeus* M.-Ed.) **sayi** S. I. Smith (Fig. 631). Carapace somewhat convex, with a dentate anterior border; male abdomen with the terminal segment triangular and somewhat broader than long;

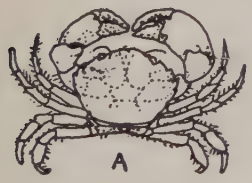

Fig. 631

Fig. 632

Fig. 633

Fig. 631—*Panopeus sayi* (Paulmeier). A, dorsal aspect; B, male abdomen. Fig. 632—*Panopeus depressus*—male abdomen (Paulmeier). Fig. 633—*Panopeus* herbsti—the large claw (Benedict).

length of carapace 17 mm.; breadth 22 mm.; color dark and dull: Massachusetts to Florida; common.

P. (*Eurypanopeus* M.-Ed.) **depressus** Smith (Fig. 632). Like *P. sayi* but with a flatter carapace and with a terminal abdominal segment in the male which forms an equilateral triangle, with arched sides; length of carapace 14 mm.; breadth 19 mm.: Cape Cod to Florida.

P. herbsti M.-Ed. (Fig. 633). Carapace with a dentate anterior border and with a tubercle just beneath the first tooth; the larger claw with a stout tubercle at the base of the movable segment; terminal abdominal segment in male rounded; length of carapace 40 mm.; breadth 60 mm.: Long Island Sound to Florida; near high-water mark.

Family 3. PORTUNIDAE.

Swimming crabs. Carapace broader than long and with a well-defined serrate, anterior margin; the last pair of periopods broad and

* See "The Genus Panopeus," by James E. Benedict and Mary J. Rathbun, Proc. U. S. Nat. Mus., Vol. 14, p. 355, 1891.

flattened at the end, and except in *Carcinides mœnas* not pointed, forming effective paddles: 7 American species.

1. **Callinectes*** Stimpson. Carapace about twice as broad as long, the anterior margin forming a serrated arch, at each end of which is a long, sharp spine: about 4 species on the coast of the southern states.

Fig. 634—*Callinectes sapidus* (Rathbun).

C. sapidus Rathbun (*C. hastatus* Say). Blue or edible crab (Fig. 634). Length of carapace 7 cm.; breadth 13 cm.; color dark green; feet blue: Cape Cod to Louisiana, common on muddy bottoms in shallow, brackish or even fresh water, often swimming among seaweed or near the surface; next to the lobster our most important food crustacean.

2. **Ovalipes** Rathbun (*Platyonichus* Latreille). Carapace not very broad, being almost round, with 5 acute teeth on each side of the anterior margin; 1 species.

O. ocellatus (Herbst). Lady crab (Fig. 635). Length of carapace 5 cm.; breadth 6 cm.; color light with red spots: Cape Cod to the Gulf of Mexico, on sand beaches; is used for food in the South.

Fig. 635

Fig. 636

Fig. 635—*Ovalipes ocellatus* (Rathbun). Fig. 636—*Carcinides mœnas* (Rathbun).

3. **Carcinides** Rathbun (*Carcinus* Leach). Carapace slightly broader than long; chelipeds rather short; last pair of thoracic feet flattened but with pointed tips: 1 species.

C. mœnas (L.). Green crab (Fig. 636). Carapace with 5 large, acute teeth on the forward margin on each side; length 4 cm.; breadth 5 cm.; color green, mottled with yellow: Cape Cod to New Jersey; Europe, where it is used for food; among the rocks in shallow water; breeding season in spring.

* See "The Genus Callinectes," by Mary J. Rathbun, Proc. U. S. Nat. Mus., Vol. 18, p. 349, 1895.

Division 3. CATOMETOPA.*

Carapace more or less rectangular, with a wide, straight anterior margin and a straight but narrower hinder margin; no rostrum present: 4 families, including the land and strand crabs, which are among the most active and intelligent crabs.

Key to the families of *Catometopa* here described:

a_1 Carapace soft and membranous; in oyster or mussel shells. 1. Pinnotheridae
a_2 Carapace hard and firm. . . . . 2. Ocypodidae

Family 1. PINNOTHERIDAE.

Carapace nearly circular and more or less membranous; eye stalks very small: small crabs, the females of which live in the mantle cavity of certain pelecypods or in annelid tubes, the males being free-swimming; 1 genus.

Fig. 637 *Pinnotheres maculatus* (Verrill).

Pinnotheres Latreille. With the characters of the family: several species.

P. ostreum Say. Oyster crab. Surface of body smooth and shiny; length and breadth of carapace about 5 mm.: in the mantle cavity of the oyster.

P. maculatus Say. Mussel crab (Fig. 637). Surface hairy; length and breadth about 8 mm.: in the mantle cavity of *Mytilus edulis* and other bivalves, from Cape Cod to South Carolina.

Family 2. OCYPODIDAE.

Carapace broad anteriorly and more or less quadrangular; eye stalks long, each lying in an elongated groove-like orbit: 6 American genera.

1. Ocypode† Fabricius. Carapace square in shape, with distinct lateral margins; chelipeds small, somewhat unequal; other periopods flat, with pointed tips; eye stalks stout: 1 American species.

O. albicans‡ Bosc (*O. arenaria* Say). Sand crab. Length of carapace 30 mm.; breadth 35 mm.; chelipeds of nearly the same size in both sexes; claw with serrated margins: New Jersey to Florida and southwards, living in deep burrows above high-water mark; a very active crab which has become a terrestrial animal.

2. Uca§ Leach (*Gelasimus* Latreille). Fiddler crabs. Chelipeds of male of very unequal size, one, usually the right, being enormously devel-

* See "The Catometopous or Grapsoid Crabs of North America," by Mary J. Rathbun, Am. Nat., Vol. 34, p. 583, 1900.

† See "Carcinological Notes, No. 111, Revision of the Genus Ocypoda," by J. S. Kingsley, Proc. Acad. Nat. Sci., Phil., for 1880, p. 179.

‡ See "Habits, Reactions, and Associations in *Ocypoda arenaria*," by R. P. Cowles, Monograph No. 103, Carn. Inst. of Wash., 1908.

§ See "Carcinological Notes, No. 11, Revision of the Gelasimi," by J. S. Kingsley, Proc. Acad. Nat. Sci., Phila., for 1880, p. 135.

oped and carried across the front of the body; eye stalks very long and slender; color light brown, mottled with purple and dark brown: small, active crabs, living in burrows, often a foot or two deep, in salt marshes and on mud and sand flats; they are frequently seen in large droves, and have the habit of slowly waving the large claw back and forth, probably a threatening attitude; numerous species; cosmopolitan; about 7 American species.

Fig. 638—*Uca minax* (Paulmeier).

U. pugnax (S. I. Smith). Inner surface of large claw with an oblique ridge, beneath which are granules; length of carapace 15 mm.; width 23 mm.: Cape Cod to Florida; common in salt marshes.

U. minax (Le Conte) (Fig. 638). Legs with red patches at the articulations; large claws with an oblique ridge on the inner surface; length of carapace 25 mm.; width 38 mm.: Cape Cod to Florida; the largest of the fiddlers, common in salt marshes, usually farther from the sea than the other species, being frequently where the water is fresh.

U. pugilator (Bosc). Length of carapace 15 mm.; width 21 mm.; inner surface of large claw without oblique ridge: Cape Cod to Florida, on sandy or muddy beaches near high-water mark.

Class 2. **ARACHNOIDEA.**

Arthropods without antennae, in which the body is usually made up of two divisions, the cephalothorax and the abdomen, the former representing the fused head and thorax and bearing six pairs of appendages, and the latter being in most cases without appendages. The class contains 2 subclasses.

Key to the subclasses of *Arachnoidea:*

a_1 Marine arachnoids of large size, with appendages bearing gills on the abdomen, and a long spike-like telson.....1. Xiphosura

a_2 Mostly terrestrial arachnoids without abdominal appendages..2. Arachnida

Subclass 1. XIPHOSURA.*

King or horseshoe crabs. Large crab-like arachnoids, in which the body consists of a cephalothorax, an abdomen, and a long spike-like telson or tail. The cephalothorax is horseshoe-shaped and unsegmented and with an arched dorsal surface, in the center of the ventral surface of which is the mouth. Six pairs of elongate appendages surround the mouth, the anterior five of which are chelate, the sixth pair terminating

* See "Xiphosura," Camb. Nat. Hist., Vol. 4, p. 259, 1909.

with a number of movable projections called the pushers, because they are used by the animal in pushing itself through the sand and mud. The first pair lie in front of the mouth, and are called the mandibles or chelicerae: they are much smaller than the others, but have the same shape. The basal joints of the remaining five pairs of legs are spiny and assist in chewing the food. The abdomen bears six pairs of appendages, none of which are leg-like. The first pair are called the operculum and form together a broad plate which falls over and covers the remaining five pairs; these are also plate-like and bear on their hinder surfaces numerous thin gills. The males are smaller than the females and differ from them in the structure of the second pair of appendages, the claw of which is a thickened structure, of use in holding on to the shell of the female while pairing. The paired genital openings are at the base of the operculum. The telson may be as long as the rest of the body.

The dorsal surface of the cephalothorax bears two large lateral composite eyes and a pair of small median ones. The dorsal surface of the abdomen is flattened and bears a row of movable spines on each lateral edge. The internal anatomy is essentially arachnid in character.*

The king crab lives in shallow water along the shore, where it burrows in the sand and mud and eats worms and other small animals. It comes to sandy beaches in the early summer to breed, and lays its eggs in depressions it makes in the sand. The embryo as it emerges from the egg has a resemblance to a trilobite and lacks the spine-like telson and the abdominal appendages. The animals, although of large size, have little economic importance. They are, however, sometimes fed to chickens and pigs.

History.—The American *Limulus* was first made known in 1590 by Thomas Harriot in his description of the animals and plants of Virginia. The Asiatic species became known during the 17th century, the dried shells having frequently been brought to Europe as curiosities. Until quite recently zoologists have placed *Limulus* among the crustaceans. Latreille, however, in 1808 called attention to its peculiar structure and created for it the separate order *Xiphosura,* and Straus-Dürckheim in 1829 emphasized its resemblance to arachnids. This idea, however, gained ground very slowly, although Huxley and von Beneden both spoke in favor of it, and it was not until after Lankester's demonstration in 1881 that *Limulus* was finally accepted as an arachnid.† Another question of relationship with which *Limulus* has to do is whether the primitive arachnid

* See "The Embryology of Limulus," by J. S. Kingsley, Jour. Morph., Vol. 7, p. 35, and Vol. 8, p. 195, 1892-3. "Studies on Limulus," by W. Patten and W. A. Redenbaugh, Jour. Morph., Vol. 16, p. 1 and p. 91, 1900.

† See "Limulus an Arachnid," by E. R. Lankester, Quart. Jour. Mic. Sci., Vol. 21, 1881.

group from which it sprang is allied to the vertebrates and thus may be the ancestor of this important class, as is maintained by Patten and others.*

The subclass contains the single genus *Limulus*. A few years ago, however, a new classification was proposed subdividing this genus into three, which were grouped in two subfamilies: this classification has not been generally adopted.

Limulus O. F. Müller. With the characters mentioned: 5 species, of which 4 inhabit the eastern coast of Asia and its islands.

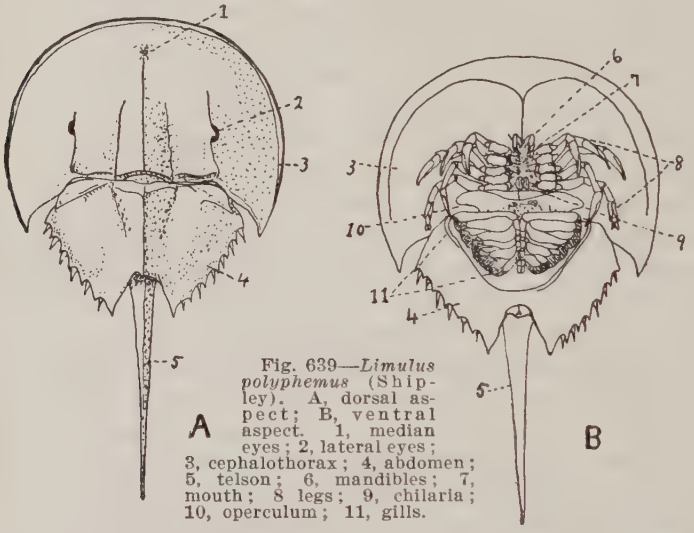

Fig. 639—*Limulus polyphemus* (Shipley). A, dorsal aspect; B, ventral aspect. 1, median eyes; 2, lateral eyes; 3, cephalothorax; 4, abdomen; 5, telson; 6, mandibles; 7, mouth; 8 legs; 9, chilaria; 10, operculum; 11, gills.

L. polyphemus (L.) (Fig. 639). Length up to 50 cm.; color dark brown: eastern coast of North America from Nova Scotia to Florida; common.

Subclass 2. ARACHNIDA.

With rare exceptions air-breathing, terrestrial animals, without antennae and with a body consisting of a cephalothorax and an abdomen.

External Structure.—The cephalothorax bears six pairs of appendages, the mandibles or chelicerae, the pedipalps, and the four pairs of walking legs. The abdomen is without locomotory appendages. The boundary between these two body divisions is usually distinct, but in the mites it is obliterated. In the spiders as well as the mites segmentation has mostly disappeared and the body is short and compact. In contrast to these forms are the scorpions, in which the body is long and vermiform, with distinct segmentation. In the *Solpugida* the head is distinct from the thorax and bears the first three pairs of appendages. The mandibles

* See "The Evolution of the Vertebrates and Their Kin," by W. Patten, 1912.

are short and end, on each side, either in a sharp, piercing claw, as in spiders, or in a pincer-like claw, as in scorpions. The pedipalps are usually sensory in function, but are prehensile organs in scorpions and many other arachnids, and in the male spider have a copulatory function. The four remaining pairs of appendages are locomotory and are usually long and slender. The abdomen in the embryo has often rudimentary appendages, the hinder three pairs of which in the spider become the spinnerets.

The cuticula of arachnids is often covered with cuticular hairs or scales, which have often an important tactile function. The special sense organs are not well developed. Eyes are generally present, but they are ocelli and not the composite eyes so characteristic of other arthropods.

Internal Structure (Fig. 654).—The digestive tract is often of complex structure. Long diverticula may extend from the stomach towards or into the legs, and a network of diverticula in the form of the so-called liver usually occupies a large part of the abdomen; one or more pairs of Malpighian or kidney tubules enter the rectum.

The respiratory organs are wanting in some mites and other minute arachnids, but are usually present in the form of lungs and tracheae. The lung is a ventral sac, usually near the anterior end of the abdomen and opening to the outside through a pore called a spiracle, which contains numerous leaf-like plates like the leaves of a book, in which the blood circulates. The tracheae are air tubes reinforced on their inner surface by a cuticular lining usually in the form of a spiral thread to keep them from collapsing, which extend from spiracles throughout the body. Scorpions and some of the larger spiders have only lungs; most spiders have both lungs and tracheae; and mites and many other arachnids have only tracheae.

Circulatory organs are wanting in many arachnids which lack a special respiratory apparatus, but in most of them a tubular heart with lateral valvular openings is present in the abdomen, from the ends of which arteries extend into the surrounding organs. The *Tardigrada* are hermaphroditic, but with this exception all arachnids are unisexual. The paired gonads lie in the ventral portion of the abdomen and open to the outside by paired ducts or by a single duct in the first or second abdominal somite. The sexes may often be distinguished by their external characters, the male being smaller than the female and often provided with special copulatory organs.

Most arachnids are oviparous, but the scorpions and a few others bear their young alive. The young usually resemble the parents in appearance, but in a few cases, as in the *Linguatulida* and the mites, they go through a metamorphosis. The great majority of arachnids are

predacious or parasitic animals, but a certain number of them, including many mites, feed on plants. All of the *Linguatulida* and about half of the species of mites are parasitic. Most arachnids are terrestrial but the *Tardigrada, Pygnogonida* and two families of the *Acarina* are aquatic.

History.—The name *Arachnida* originated with Lamarck in 1801, who at that time separated these animals from the *Insecta aptera* of Linnæus and his immediate followers. The subclass contains about 20,000 species grouped in 11 orders.

Key to the orders of *Arachnida:*

a_1 Abdomen distinctly segmented.
  b_1 Animals not parasitic.
    c_1 Long segmented postabdomen or segmented caudal filament (except the *Tarantulidae*) present.
      d_1 Postabdomen with caudal sting present.....1. SCORPIONIDA
      d_2 Caudal filament (except the *Tarantulidae*).
        e_1 Animals minute; caudal filament with segmental bristles..2. PALPIGRADI
        e_2 Animals larger; caudal filament, when present, smooth....3. PEDIPALPI
    c_2 No postabdomen or caudal filament.
      d_1 Head distinct from thorax, bearing first 3 pairs of appendages .....4. SOLPUGIDA
      d_2 Head not distinct.
        e_1 Pedipalps chelate and very long. 5. PSEUDOSCORPIONIDA
        e_2 Pedipalps not chelate; legs very long and slender. 6. PHALANGIIDA
  b_2 Animals worm-like and internal parasites in vertebrates .....9. LINGUATULIDA
a_2 Abdomen not segmented.
  b_1 Animals usually terrestrial.
    c_1 Cephalothorax distinctly separated from abdomen. 7. ARANEAE
    c_2 Cephalothorax and abdomen not distinct....8. ACARINA
  b_2 Animals aquatic.
    c_1 Animals microscopic.....10. TARDIGRADI
    c_2 Animals marine and not microscopic; legs very long and slender.....11. PYCNOGONIDA

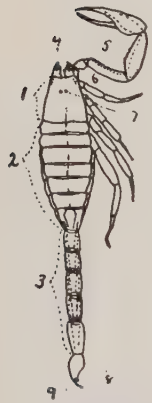

Fig. 640—Diagram of the dorsal aspect of *Centrurus* (Banks). 1, cephalothorax; 2, pre-abdomen; 3, postabdomen; 4, mandibles; 5, pedipalps; 6, lateral eyes; 7, median eyes; 8, spine; 9, sting.

ORDER 1. SCORPIONIDA.*

(Fig. 640.) Elongated arachnids with a short, unsegmented cephalothorax and a long abdomen consisting of 13 segments, of which the anterior 7 form the pre-abdomen and are about of the same diameter as the cephalothorax, and the posterior 6 form the much narrower, tail-like post-abdomen, at the end of which is a poisonous sting; 3 to 6 pairs of eyes usually present; mandibles short and chelate; pedipalps very long and

* See "Scorpiones und Pedipalpi," by K. Kraepelin, Das Tierreich, 1899. "Synopsis of the North American Scorpions, Solpugids, and Pedipalpi," by Nathan Banks, Am. Nat., Vol. 34, p. 421, 1900.

chelate; on the ventral surface the second abdominal segment bears a pair of long comb-shaped appendages called the pectines, which probably aid in the act of pairing, following which are 4 pairs of spiracles, each of which opens into a lung sac; genital opening just in front of the pectines on the first abdominal segment and protected by small paired plates, which form the sternum; the young are born alive and are carried about for a while by the mother: over 300 species, about 25 occurring in our southern and western states, ranging as far north as Nebraska; they are nocturnal animals and feed on insects and spiders which they often kill with the sting.

Key to the families of *Scorpionida* here described:

a_1 Sternum broad, pentagonal; usually no spine under the sting.
  b_1 At base of terminal segment of last pair of legs at least 1 spur on inner and 1 on outer side.....1. VEJOVIDAE
  b_2 But 1 spur present, on outer side.....2. SCORPIONIDAE
a_2 Sternum long, triangular; usually a spine under the sting...3. CENTRURIDAE

FAMILY 1. VEJOVIDAE.

Three eyes on each side; terminal joint of legs with an inner and outer spur at base; no spine under the sting: 8 genera and 18 species.

1. VEJOVIS Koch. Median lamella of each comb divided into at least 8 small pieces; lower margin of the movable finger of mandible without spines: 6 American species.

V. boreus (Girard). Hand strongly keeled; color yellowish or greenish: Nebraska and westerly to Nevada and Idaho.

V. mexicanus Koch. Hand less distinctly keeled; color brown, not spotted; legs reddish; length 8 cm.; number of teeth of comb 15 to 22: Texas.

V. carolinus Koch. Color reddish-brown; legs yellow; length 34 mm.; number of teeth of comb 13 or 14: southern Atlantic states and into Kansas and Texas; California.

2. HADRURUS Thorell. Large, hairy scorpions with a large, dark spur near the tip of the lower margin of the movable finger of the mandible: 2 species.

H. hirsutus (Wood). Color yellowish-red; length 7 cm.; number of teeth of comb 25 to 40; legs compressed: California and Arizona.

FAMILY 2. SCORPIONIDAE.

Sternum pentagonal in shape; but 1 spur at the base of the last tarsal joint, which is on the outer side; usually no spur under the sting: 15 genera and about 88 species.

DIPLOCENTRUS Peters. With a hump under the sting: 6 species, all American.

D. whitei (Gervais). Color yellow or brown; terminal joint of foot with a row of about 7 spines running up from the claw; teeth of comb 12 to 18; length 5 cm.: Texas to California.

Family 3. CENTRURIDAE.

Sternum small and triangular, the sharp end in front; a spur on the under side of the unmovable finger of the mandible: 4 genera and about 50 species, many American.

Centrurus Ehrenberg (Fig. 640). The oblique rows of teeth on the finger of the pedipalp have on each side a parallel row of minute teeth; under the sting may be a spine: 15 American species.

C. carolinianus (Beauvois). Color yellowish, with small spots, often joined into 2 longitudinal stripes; length 7 cm.; teeth of comb, 19 to 25: southern states.

Order 2. PALPIGRADI.*

Minute arachnids with a segmented abdomen, from the hinder end of which a long segmented caudal filament with segmental bristles projects; mandible long and chelate; pedipalps and the 4 pairs of legs rather long and slender; no eyes; cephalothorax of 3, abdomen of 11 segments: 1 genus with a few species, which have been found in Italy, Siam, Paraguay, and Texas.

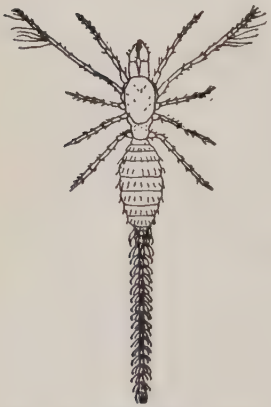

Fig. 641—*Kœnenia wheeleri* (Wheeler).

Kœnenia Grassi. With the characters above mentioned: 2 American species.

K. wheeleri† Rücker (Fig. 641). Length with filament up to 2.5 mm.; color white; 3 pairs of eversible lung sacs on segments 4 to 6: under stones in moist places near Austin, Texas.

Order 3. PEDIPALPI.‡

Cephalothorax separated by a constriction from the abdomen, which is 11 or 12-jointed; last 3 pairs of legs used for walking; in the first

* See "Palpigradi und Solifugae," by K. Kraepelin, Das Tierreich, 1901.

† See "A Singular Arachnid," etc., by W. M. Wheeler, Am. Nat., Vol. 34, p. 837, 1900. "The Texas Kœnenia," by Augusta Rücker, Am. Nat., Vol. 35, p. 615, 1901. "A New Kœnenia from Texas," by same, Q. J. M. S., Vol. 47, p. 401, 1903.

‡ See "On the Pedipalpi of North America," by H. C. Wood, Jour. Acad. Nat. Sci., Phila., Vol. 5, p. 357, 1863. "Scorpiones und Pedipalpi," by K. Kraepelin, Das Tierreich, 1899. "Synopsis of North America Pedipalpi," by N. Banks, Am. Nat., Vol. 34, p. 421, 1900.

pair the terminal portion very much elongated and forming a long, many-jointed tactile flagellum; pedipalps thick and strong and, like the mandibles, either chelate or not; 2 pairs of book lungs on the third and fourth abdominal segments; 8 eyes usually present, 2 large ones in front and 3 small ones on each side; genital pores paired and on the first abdominal segment: predacious tropical animals, 5 species of which are found along the southern border of this country; 3 families and about 60 species.

Key to the families of *Pedipalpi* here described:

a_1 Long filiform tail present.....1. THELYPHONIDAE
a_2 No such tail.....2. TARANTULIDAE

FAMILY 1. THELYPHONIDAE.

Whip scorpions. Body elongate; pedipalps chelate; abdomen 12-jointed, the last 3 segments smaller than the others and bearing a long, jointed terminal filament and also often ommatoids, white ocellus-like spots: 10 genera and about 40 species.

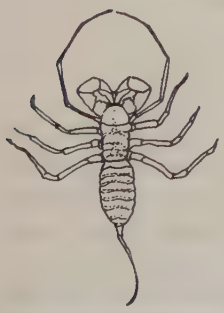

Fig. 642.—*Mastigoproctus giganteus* (Comstock).

MASTIGOPROCTUS Pocock. Two ommatoids present: 17 species.

M. giganteus (Lucas). Vinegar roan (Fig. 642). Length (with tail) 13 cm.; color dark brown; tail with reddish hairs; animal has a strong odor of vinegar: Florida to Arizona, often common in dry sandy places; they are nocturnal animals which are much feared, although they are not poisonous.

FAMILY 2. TARANTULIDAE.

Body broad, cephalothroax being broader than the abdomen and joined with it by a slender waist; pedipalp ends with a claw; abdomen 11-jointed and without a terminal filament: 10 genera and about 18 species.

Fig. 643
Tarantula whitei (Banks).

Tarantula Fabricius. Foot with a single claw; front margin of celphalothorax either with short teeth or smooth: 4 species, all American.

T. whitei (Gervais) (Fig. 643). Front margin of cephalothorax denticulate; inner margin of pedipalp with long spines; color brown with a yellow margin; length 20 mm.: Texas to California.

Order 4. SOLPUGIDA.* (Solifugae.)

Head region separated from the thorax and bearing very large chelate mandibles, the leg-like pedipalps, and the first pair of legs, as well as a pair of eyes; thorax consists of 3 distinct segments, each bearing a pair of legs; abdomen 10-jointed; respiration by tracheae, the first pair of spiracles being on the thorax, the other 3 pairs being on the abdomen; genital pore in first abdominal segment: usually nocturnal animals which live in sandy deserts in the warmer parts of the earth; 3 families with about 165 species, a few of which are found in this country, chiefly in the southwest; they are much feared, although not poisonous.

Family SOLPUGIDAE.

Second and third pair of abdominal spiracles not covered with denticulate plates: 21 genera and about 145 species.

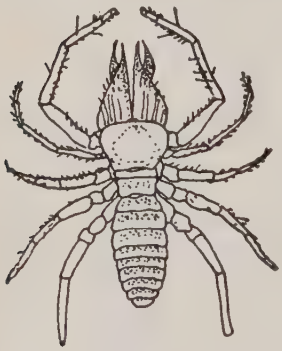

Fig. 644—*Eremobates formidabilis* (Kingsley).

Eremobates Banks (*Datames* Simon). Anterior margin of head truncate; fourth pair of legs without a terminal claw; dorsal finger of mandible without teeth or spur: about 18 species, all in America.

E. pallipes (Say). The movable segment of the mandibles in the male with 1 large and sometimes 1 very small tooth; the inner side of the pedipalp of male hairy and without bristles; length 13 mm.; color light yellow: southern states west of Mississippi, north into Kansas and Colorado.

E. formidabilis (Simon) (Fig. 644). Movable segment of the mandible slender and with 1 large and 2 small teeth: California and Arizona.

Order 5. PSEUDOSCORPIONIDA.†

Small arachnids with an 11-jointed abdomen, with chelate mandibles, the movable finger of which bears along its inner margin the comb-

* See "The Solpugidae of America," by J. D. Putnam, Proc. Davenport Acad. Nat. Sci., Vol. 3, p. 1, 1882. "Synopsis of the North American Solpugida," by N. Banks, Am. Nat., Vol. 34, p. 426, 1900. "Palpigradi und Solifugae," by K. Kraepelin, Das Tierreich, 1901.

† See "Notes on North American Chernetidae," by N. Banks, Cand. Entom., Vol. 23, 1893. "Notes on the Pseudoscorpionidae," by N. Banks, Jour. N. Y. Entom. Soc., Vol. 3, 1895. "Habits and Distributions of the Pseudoscorpionidae, principally Chelanops oblongus, Say," by E. W. Berger, Ohio Nat., Vol. 6, p. 407, 1905. "A List of the North American Pseudoscorpionida," by K. R. Coolidge, Psyche, Vol. 15, p. 108, 1908.

shaped serrula (Fig. 645, B), and with long scorpion-like pedipalps; legs long, 5-jointed, and ending with 2 claws; eyes present or not; respiration by tracheae, 2 pairs of spiracles being present on the second and third abdominal segments; genital pore in the second abdominal segment, in the female surrounded by cement glands, the secretion of which serves to fasten the eggs to the body of the mother; silk glands open to the outside near the tip of the movable finger of the mandible; the animals spin nests, in which they spend the winter or can retire during a moult; no poison glands present: under the bark of trees, among moss or dead leaves, or in houses, on old books, or furniture, where they eat mites and small insects; occasionally they attach themselves for purposes of migration to insects; they run rapidly forwards, backwards, or sideways; 3 families with 100 species.

Key to the families of *Pseudoscorpionida* here described:

a_1 Cephalothorax with a transverse suture; two eyes or none usually present .....1. CHELIFERIDAE

a_2 No such suture; four eyes usually present.....2. OBISIIDAE

FAMILY 1. CHELIFERIDAE.

Spinneret on mandible long and tubular; serrula attached along its whole length; 2 eyes or none present: 5 genera.

1. CHELIFER Geoffroy. Cephalothorax triangular, rounded in front and divided by transverse sutures into 3 parts; 2 eyes present; mandibles small: several species.

C. cancroides (L.). Book scorpion (Fig. 645). Length 3 mm.; color reddish-brown; dorsal abdominal plates divided by a median line; basal

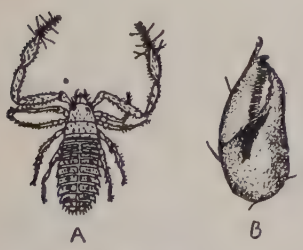

Fig. 645

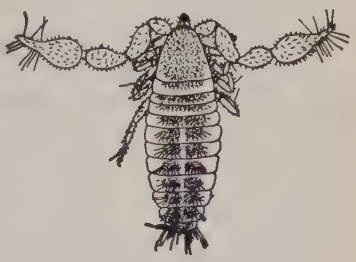

Fig. 646

Fig. 645—*Chelifer cancroides*. A, dorsal aspect (Leunis); B, mandible (Comstock).
Fig. 646—*Chelanops oblongus* (Berger).

portion of pincer thick, terminal finger curved: often found in houses on old books, furniture, or clothing; cosmopolitan.

C. biseriatum Banks. Body 2.2 mm. long, pale yellowish in color, with 2 rows of dark spots on the abdomen; pedipalps very slender; no large granules on cephalothorax: Florida; Ohio; Jamaica.

C. muricatus Say. Body 2.5 mm. long and reddish-brown in color; hand of pedipalp very much darker than the rest: eastern states, among dead leaves.

2. **Chelanops** Nicolet (*Chernes* Menge). Similar to *Chelifer* but without eyes: about 19 American species.

C. oblongus (Say) (Fig. 646). Body 3.5 mm. long, elongate and elliptical in shape, being widest in the middle, reddish-brown in color, being darker on the cephalothorax; a double row of large dark spots on the abdomen, from each of which a number of long bristles spring: widely distributed over the eastern and central states; under stones near low-water mark at Woods Hole.

C. tristis Banks. Body 2 mm. long, pale reddish-yellow in color with soft parts and legs white; abdomen elliptical, the dark spots on the dorsal plates being much nearer the median than the lateral line: the seashore of Long Island.

C. sanborni Hagen. Body 2 mm. long, very broad, and reddish-brown in color; pedipalps short and heavy with clavate hairs: eastern states, under bark.

Family 2. OBISIIDAE.

Spinneret a small knob; serrula attached only at the base; 4 eyes usually present: 4 genera.

1. **Obisium** Leach. Cephalothorax rectangular and not narrower in front; pedipalps short and stout; 4 eyes present; fingers curved: 6 species in America.

O. muscorum Leach. Body 2.5 mm. long, brownish in color: in moss.

2. **Chthonius** Koch. Cephalothorax rectangular and wider in front; mandibles large; fingers straight: about 5 American species.

C. pennsylvanicus Hagen. Length 1.9 mm.; color brownish, with scattered silvery spots on the abdomen; legs white; pedipalps longer than the body; 4 eyes, not close together: eastern United States.

Order 6. PHALANGIIDA.*

Harvestmen or daddy longlegs. Body short, ovoid in shape, with an unsegmented cephalothorax which is joined with the 9-jointed abdomen without any constriction; mandibles chelate; pedipalps long and leg-like, each ending with a claw; legs usually very long and slender, the basal portion of the anterior pairs possessing chewing plates; the body

* See "On the Phalangeae of the United States," by H. C. Wood, Commun. Essex Inst., Vol. 6, p. 10, 1868. "A Descriptive Catalogue of the Harvest Spiders (Phalangiidae) of Ohio," by C. M. Weed, Proc. U. S. Nat. Mus., Vol. 16, p. 543, 1893. "Synopsis of North American Phalangida," by N. Banks, Am. Nat., Vol. 35, p. 669, 1901.

of the male somewhat smaller and with longer legs than the female; a pair of simple eyes present, one being on each side of a tubercle rising in the middle of the cephalothorax; genital opening between the last pair of legs in a forward prolongation of the ventral plate of the first abdominal segment from which also extends a long protrusible penis or ovipositor (Fig. 648, 2); a pair of stink glands on the abdomen, which often become active when the animal is handled; respiration by tracheae, usually a single pair of spiracles being present on the first abdominal segment; eggs laid in the ground or in other moist places in the summer or autumn and the young, which are like the adults in appearance, usually hatch the following spring: about 60 species in America, grouped in 7 families; animals more or less nocturnal, probably feeding principally on small insects, spiders, and mites, but also occasionally on decaying substances; they do not spin a web or build a nest.

Key to the families of *Phalangiida* here described:

a_1 Last segment of pedipalp with a terminal claw and longer than the preceding one. 1. PHALANGIIDAE

a_2 No such claw and the last segment much shorter than the preceding one. 2. NEMASTOMATIDAE

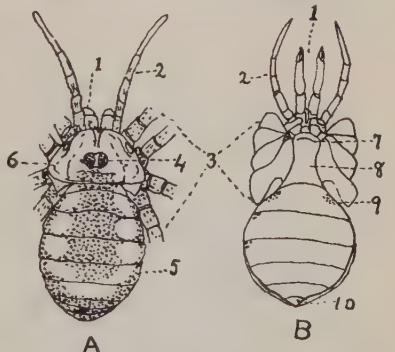

Fig. 647—A, dorsal view of a phalangid; B, ventral view of a phalangid (Banks). 1, mandibles; 2, pedipalps; 3, legs; 4, eye tubercle; 5, abdomen; 6, cephalothorax; 7, genital pore; 8, forward prolongation of abdomen; 9, spiracle; 10, anus.

FAMILY 1. PHALANGIIDAE. (FIG. 647.)

Body ovoid with a leathery integument; pedipalp ending with a claw; legs long and slender, with a simple terminal claw on each: about 15 American genera.

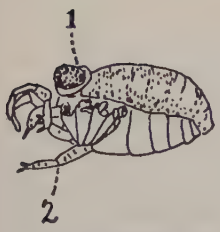

Fig. 648—*Caddo agilis* (Comstock). 1, eye; 2, ovipositor.

Key to the genera of *Phalangiidae* here described:

a_1 Eye tubercle of enormous size.....1. CADDO

a_2 Eye tubercle of normal size.....2. LIOBUNUM

b_1 Eye tubercle smooth.

b_2 Eye tubercle spinose.....3. PHALANGIUM

1. CADDO Banks. Eye tubercle of enormous size; 3 long spines on femur of pedipalp: one species.

C. agilis Banks (Fig. 648). Body 3 mm. long, brown in color, with 2 pale stripes above: among dead leaves and moss.

2. Liobunum Koch. Anterior and lateral borders of cephalothorax not spinose; eye tubercle rather small and smooth; legs usually very long and slender: 16 American species.

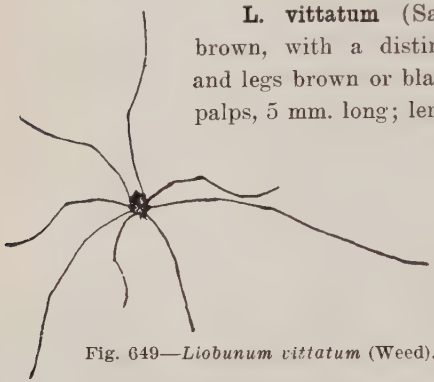

Fig. 649—*Liobunum vittatum* (Weed).

L. vittatum (Say) (Fig. 649). Body reddish-brown, with a distinct mid-dorsal stripe; pedipalps and legs brown or black; length about 9 mm.; of pedipalps, 5 mm. long; length of legs, first, 42 mm., second, 90 mm., third, 43 mm., fourth, 61 mm.: eastern and central America; common in fields and woods.

L. politum Weed (Fig. 650). Body reddish-brown; pedipalps light brown, legs black; eye tubercle rather prominent, with a row of small black projections over each eye; length about 5 mm.; pedipalps 2.8 mm. long; length of legs, first, 25 mm., second, 51 mm., third, 26 mm., fourth, 36 mm.: eastern and central states, in fields and woods; common.

L. grande (Say). Body blackish and tuberculate, 9 to 12 mm. long; pedipalps 6 mm. long; length of legs, first, 20 mm., second, 35 mm., third, 21 mm., fourth, 28 mm.: eastern and central states.

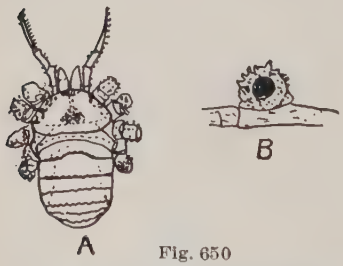

Fig. 650

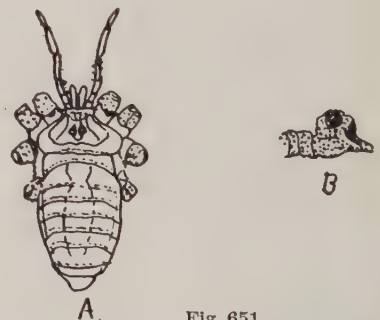

Fig. 651

Fig. 650—*Liobunum politum* (Weed). A, dorsal aspect after the removal of the legs; B, side view of the eye tubercle. Fig. 651—*Liobunum ventricosum* (Weed). A, dorsal aspect after the removal of the legs; B, side view of the eye tubercle.

L. ventricosum (Wood) (Fig. 651). Body elongate; legs and body cinnamon or yellowish-brown; length 7 to 10 mm.; length of legs, pedipalps, 5 mm., first, 33 mm., second, 64 mm., third, 33 mm., fourth, 48 mm.: eastern and central states; common.

3. Phalangium L. Anterior and lateral borders of cephalothorax spinose; eye tubercle with 2 series of spines: 2 species in America.

P. cinereum Wood (Fig. 652). Body gray, sometimes brownish, usually with a wide lenticular mid-dorsal marking, and about 8 mm. long; pedipalps 4 mm. long; length of legs, first, 20 mm., second, 52 mm., third, 29 mm., fourth, 36 mm.: northern America, on walls, etc., rarely in the open field.

Fig. 652—*Phalangium cinereum* (Weed). A, dorsal aspect after the removal of the legs; B, eye tubercle.

Family 2. NEMASTOMATIDAE.

Pedipalps long and prominent, with last joint much shorter than the preceding one and without a claw: 3 genera.

Phlegmacera Packard. Mandibles directed downwards and not forwards; fourth joint of pedipalp much thickened; body somewhat compressed and not spiny: 3 species.

P. cavicolens Pack. Body 4 mm. long and 2 mm. wide; eyes large and prominent; eye tubercle very low; a series of large transverse dark spots on back; movable finger of mandible with about 24 setae: in caves and similar places; eastern and central states.

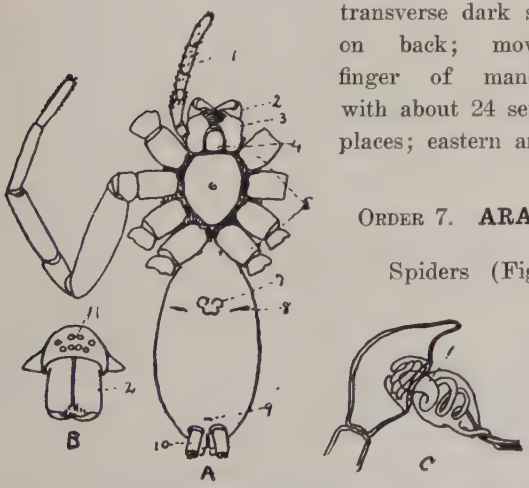

Fig. 653—A, diagram of the ventral aspect of a spider; B, front of head (Emerton); C, palpal organ of male (Warburton). 1, pedipalp; 2, mandible; 3, maxilla; 4, labium; 5, legs; 6, sternum; 7, epigynum; 8, lung spiracle; 9, tracheal spiracle; 10, spinnerets; 11, eyes.

Order 7. **ARANEAE.*** (Araneida.)

Spiders (Fig. 653). Cephalothorax and abdomen mostly unsegmented and united by a slender waist. The body is often covered with hairs or scales, and gray or dark in color when the animal lives on or near the ground, but is often brightly colored when it lives on flowers, shrubs, or trees. Of the six pairs of appendages the mandibles or chelicerae are the most anterior; they are two-

* See "Catalogue of the Described Araneae of Temperate North America," by Dr. George Marx, Proc. U. S. Nat. Mus., Vol. 12, 1889. "American Spiders," etc., by Henry C. McCook, 1889-1893. "Histoire Naturelle des Araignées," by E. Simon, Paris, 1897-1904, 2nd Ed. "The Common Spiders of the United States," by James H.

jointed, the terminal joint being a sharp claw, near the end of which is the opening of a poison gland. The mandibles are usually directed downwards so that the spider must strike when its prey is beneath it. The second pair of appendages are the pedipalps or palpi, which are leg-like in form and composed of six segments; the large and flattened basal segments of these are called the maxillae or endites and extend forwards, forming the principal jaws of the animals, being used to chew or squeeze the food.

In the male the end of the pedipalp is enlarged and bears the more or less complicated palpal organ by which sperm is conveyed to the female in the act of pairing (Fig. 653, C). The four pairs of long walking legs are seven-jointed. The tarsus or terminal joint of each leg bears a pair of claws, the inner edge of each of which is toothed; in many spiders a third smaller claw is also present and in others a thick brush of hairs. Between the maxillae is a plate called the labium or lip, and between the base of the legs is the sternum. The abdomen bears at its hinder end, just in front of the anus, usually 3 pairs of spinnerets, which are modified legs (Fig. 655). At the end of each spinneret are minute tubes which are the ends of the ducts of the silk glands; the fluid silk coming out of these tubes unites to form a single strand, and hardens on exposure to the air. In a few families a plate called the cribellum lies in front of the spinnerets from which spinning tubes also project; such spiders have a row or comb of stiff hairs on each of the hind legs called the calamistrum (Fig. 655) by means of which a band of silk may be spun. All the spinning tubes do not exude the same kind of silk, but a variety of kinds is produced which are used for various purposes, as for making the different parts of the web, nests, cocoons, etc.

Spiders are not well provided with special sense organs. The long legs and the hairs usually covering the body are tactile organs, and in most spiders eight simple eyes are present on the front portion of the cephalothorax usually in two rows, enabling the spider to see a short distance (Fig. 653, B).

The respiratory organs of spiders consist of two pairs of lungs in the *Tetrapneumones,* which are situated in the forward part of the abdomen and open to the outside by slit-like spiracles on the ventral surface; in the *Dipneumones* one pair of lungs is present and a pair of tracheae, the latter opening in most cases through a single spiracle in front of the spinnerets. Each of the lung spiracles is covered with an integu-

Emerton, 1902. "Families and Genera of the Araneida," by Nathan Banks, Am. Nat., Vol. 34, p. 293, 1905. "Fauna of New England. A List of the Araneida," by Elizabeth B. Bryant, Bost. Soc. Nat. Hist., Occ. Papers, No. 7, 1908. "Catalogue of Neartic Spiders," by N. Banks, Bull. No. 22, U. S. Nat. Mus., 1910. "The Spider Book," by J. H. Comstock, 1912.

mental fold, and between them is the genital pore which, in the female, is covered by a plate, often complex in structure, called the epigynum.

The arrangement of the internal organs of spiders will be seen in the accompanying diagram (Fig. 654).

Spiders prey principally upon insects, but will usually kill and devour any animal smaller than themselves, including their own kind. The female not infrequently eats the smaller male when he approaches her at pairing time. Spiders may be divided, as to their method of taking their prey, into 2 groups: (1), the hunting spiders, which run on the ground or on plants and spring upon their prey, usually from a concealed retreat, and (2), cobweb spiders, which make webs to catch flying insects. The hunting spiders often make nests of silk; the cobweb spiders usually live in their webs or in nests near them.

The webs are of 4 kinds: (1), the very irregularly woven web of the house spider *Theridion tepidariorum* and other *Theridiidae* (Fig. 664); (2), the more or less irregular web of the *Linyphiidae* and some other spiders, the most important part of which consists of a large, flat or curved sheet held down by threads in all directions (Fig. 665); (3), the funnel webs of the *Agelenidae,* consisting of a flat sheet and a funnel leading to a retreat; (4) the round webs of the *Epeiridae,* composed of threads radiating from a common center, with cross threads (Fig. 667).

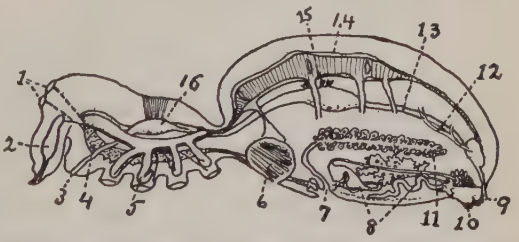

Fig. 654—Internal anatomy of a spider (Shipley). 1, eyes; 2, poison gland; 3, mouth; 4, brain; 5, diverticulum of the stomach; 6, lung; 7, genital pore; 8, silk glands; 9, anus; 10, spinnerets; 11, ovary; 12, kidney tubule; 13, intestine; 14, heart; 15, liver ducts, the liver having been removed; 16, sucking stomach.

Spiders lay spherical eggs which the female winds with silk into a spherical or oblong mass called the cocoon; this the spider often carries about for awhile in the mandibles or attached to the spinnerets, and fastens in the web or to grass or other objects, or hides in her nest. Some spiders construct burrows in the ground in which they deposit their cocoons. Spiders live usually less than a year. Great numbers, the adults of which die in the autumn on the approach of cold weather, pass the winter in the form of eggs, while others lie torpid among leaves on the ground and in other protected places. Spiders are born with the form of the parent, but often differ from them at first very much in appearance; they are also sexually dimorphic, the males being smaller than

the females, possessing the palpal organ, and often being differently marked.

Over 10,000 species are known, of which 1,300 belong in this country. The order contains 2 suborders and about 26 families.

Key to the suborders of *Araneae:*

a_1 Two pairs of lungs; usually 2 pairs of spinnerets: claw of mandible vertical in position.....1. TETRAPNEUMONES

a_2 One pair of lungs; 3 pairs of spinnerets: claw of mandible horizontal in position, working from the side, medially.....2. DIPNEUMONES

SUBORDER 1. TETRAPNEUMONES.

Often large spiders with 2 pairs of lungs and 2 or 3 pairs of spinnerets; mandibles usually project more or less forwards, the claw of which projects downwards instead of transversely; with 8 eyes set closely together: tropical or subtropical spiders including the bird spiders and trap-door spiders; 3 families.

FAMILY AVICULARIIDAE.

Pedipalp arises near or at the tip of the maxilla, which is not distinct; the 4 lung spiracles covered by broad and often glistening folds: 40 American species.

PACHYLOMERUS* Ausserer. Trap-door spiders. Cephalothorax almost as broad as long; abdomen ovoid; spinnerets 4; eyes close together, on low prominences, the lateral eyes being the largest; the extremities of the 2 hinder pairs of legs much thickened: 8 American species, in the southern states.

P. audonini (Lucas). Length 20 mm.; the anterior lateral eyes the largest; third joint of the third pair of legs very short and crooked; color glossy brown: North Carolina; the animal lives in a cylindrical burrow in the ground lined with silk, the opening of which can be closed by a circular door which works with a hinge.

SUBORDER 2. DIPNEUMONES

Spiders with 1 pair of lungs; tracheae also present which open to the outside usually by a single spiracle; 3 pairs of spinnerets; mandibles directed downwards, the claws projecting from the side towards the median line: over 30 families.

* See "A New Trap-Door Spider," by G. F. Atkinson, Am. Nat., Vol. 20, p. 583, 1886.

Key to the families of *Dipneumones* here described:

a_1 With cribellum and calamistrum (Fig. 655).
b_1 Eyes all dark-colored (diurnal); web usually regular.....1. ULOBORIDAE
b_2 Anterior median eyes dark, the other light-colored (nocturnal); web irregular.
c_1 Lateral eyes near together.....2. DICTYNIDAE
c_2 All the eyes close together on an eminence.....3. FILISTATIDAE
a_2 Without cribellum and calamistrum.
b_1 Two terminal claws on the feet.
c_1 Six eyes; 4 spiracles; ground spiders.....4. DYSDERIDAE
c_2 Eight eyes present.
d_1 Eyes usually in 2 rows.
e_1 First 2 pairs of legs not noticeably longer than the others.
f_1 Fore spinnerets widely separated; ground spiders.....5. DRASSIDAE
f_2 Fore spinnerets contiguous; ground spiders.....11. CLUBIONIDAE
e_2 First 2 pairs of legs much longer than the others; crab spiders. 10. THOMISIDAE
d_2 Eyes in 3 rows, the middle row being much smaller than the others.
b_2 Three terminal claws on the last 3 pairs of feet. 15. ATTIDAE
c_1 Legs very long, being over 4 times the length of the body.....6. PHOLCIDAE
c_2 Legs not so long.
d_1 Eyes in 2 rows.
e_1 Hinder part of spinnerets not very long.
f_1 A comb of serrate bristles on the hind foot; abdomen often globose. 7. THERIDIIDAE
f_2 No such comb.
g_1 Basal segment of mandible with row of teeth on its outer surface; small spiders with irregular webs.....8. LINYPHIIDAE
g_2 No such mandibular teeth; usually large spiders with regular radial webs .....9. EPEIRIDAE
g_3 A semicircular notch at base of leg on penultimate segment. 13. PISAURIDAE
e_2 Hinder pair of spinnerets very long and 2 jointed. 12. AGELENIDAE
d_2 Eyes in 3 rows. ..14. LYCOSIDAE

FAMILY 1. ULOBORIDAE.

A cribellum and usually a calamistrum (Fig. 655) present; lateral eyes farther apart than the 2 pairs of median eyes; web usually round and regular, with radiating spokes joined by cross threads and composed in part of loose bands of silk: 3 genera, and 6 American species.

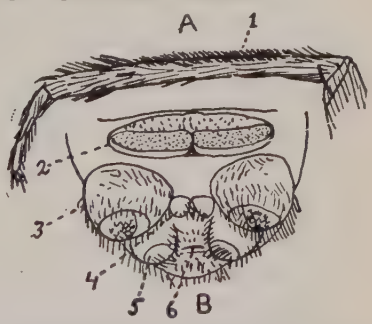

Fig. 655—A, part of fourth leg of *Amaurobius;* B, ventral view of hinder end of same. 1, calamistrum; 2, cribellum; 3, anterior spinnerets; 4, middle spinnerets; 5, posterior spinnerets; 6, anus. (Cambridge Natural History.)

1. ULOBORUS Latreille. Cephalothorax ovate, rounded behind; eyes all of about the same size: 4 American species.

U. plumipes Lucas. Length of female 7 mm.; cephalothorax low; first pair of legs in the female twice as long as the second, with a bunch of long hairs at the end of the middle segment; color brown, with a median stripe

on the cephalothorax; male without the calamistrum: common in shady woods and bushes, especially in the lower dead branches of pines.

2. Hyptiotes Walckenaer. Cephalothorax nearly circular, truncate behind; eyes of the posterior row very much larger than those of the anterior: 1 American species.

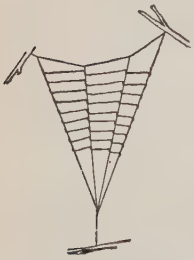

Fig. 656—Web of *Hyptiotes cavatus* (Emerton).

H. cavatus (Hentz) (Fig. 656). Length of female 5 mm.; abdomen ovoid, with 4 pairs of slight elevations covered with stiff hairs; color brown; web triangular in shape, with but 4 rays which radiate from a common strand held taut by the spider, and with cross strands: common, especially in pine woods.

Family 2. DICTYNIDAE.

With cribellum and calamistrum in female but not in male; lateral eyes near together on each side; web irregular, usually a dense network of threads with a hole into which the spider retreats, found in open places: about 35 American species.

1. Dictyna Sundevall. Small spiders with sternum extending between the hind legs; legs without spines; all the eyes of about same size; head high arched, about half as wide as the thorax and distinctly marked off from it: numerous species, about 19 in America.

D. sublata (Hentz) (*D. muraria* Emerton). Body gray in color, with dark median marking on the abdomen, and about 3 mm. long; cribellum large: web on walls, fences, weeds, etc., often conspicuous because of the dust it collects; common.

D. foliacea (Hentz) (*D. volupis* Keyserling). Body about 3 mm. long; cephalothorax brown; abdomen yellow in the middle, and brown or red at the sides; legs pale; abdomen about as wide as the cephalothorax: web in bushes; common.

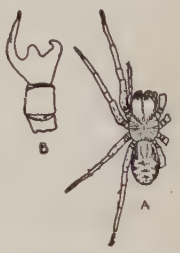

Fig. 657—*Amaurobius benneti* (Emerton). A, dorsal aspect; B, male pedipalp without terminal segment.

2. Amaurobius Koch. Sternum not extending between the hind legs; cribellum divided into 2 parts; head large and distinctly marked off from the thorax; legs with spines: about 7 American species.

A. benneti (Blackwall) (*A. sylvestris* Emerton) (Fig. 657). Body 10 mm. long; cephalothorax dark brown; abdomen gray with median yellowish markings; the epigynum has 2 lateral lobes which meet behind: web under stones and sticks; common.

A. ferox (Walckenaer). Like above, but the lateral lobes of the epigynum do not meet behind: in houses, especially cellars; an European species introduced into this country.

Family 3. FILISTATIDAE.

With cribellum and calamistrum; all the eyes close together and upon an eminence; mandibles small; web like that of *Dictyna:* 1 American species.

Filistata Latreille. With the characters of the family: 2 species.

F. hibernalis Hentz. Body 12 mm. long with legs about twice as long, and uniformly dark gray in color: one of the commonest house spiders of the southern states.

Family 4. DYSDERIDAE.*

With only 6 eyes; with a pair of tracheal spiracles immediately behind the lung spiracles: the animals build tube-like nests on the ground under stones and other objects; 3 American genera and species.

Dysdera Latreille. Eyes in a ring, close together; mandibles long and inclined forward: 1 species.

D. interrita Hentz (Fig. 658). Length 12 mm.; the abdomen but little larger than the cephalothorax; color orange brown, lighter behind: New England.

Fig. 658 *Dysdera interrita* (Emerton).

Family 5. DRASSIDAE.*

Elongated spiders with 2 claws and a bunch of flattened hairs on each leg; eyes all of the same size, usually in 2 rows; spinnerets widely separated: ground spiders which build tube or sac-like nests; about 60 American species.

1. Drassus Walckenaer. Eyes in 2 slightly curved rows, which diverge mid-dorsally, the posterior row longer than the anterior; mandibles small; maxillae straight: 9 American species.

D. neglectus Keyserling (*D. saccatus* Emerton). Length 20 mm.; color light gray, without markings; abdomen but little longer than the cephalothorax: the animal lives under stones and makes a large transparent bag of silk in which the cocoon is deposited; common.

2. Gnaphosa Latreille. Eyes in 2 nearly straight rows, the upper row longer than the lower; those of the middle pair of the upper row being much nearer each other than the lateral eyes: 10 American species.

G. gigantea Keyserling (*G. conspersa* Thorell). Length 12 mm.; color rusty black; cephalothorax and abdomen of about the same size; mandibles large, with a wide serrate tooth under the claw: under stones and leaves.

3. Sergiolus Simon. Maxillae arched around the labium; the 2 rows of eyes nearly straight; no dorsal groove: 3 American species.

* See "New England Spiders of the Families Drassidae, Agelenidae, and Dysderidae," by J. H. Emerton, Trans. Conn. Acad., Vol. 8, p. 1, 1890.

S. variegatus (Hentz) (Fig. 659). Length 6 mm.; cephalothorax bright orange in color and smaller than the abdomen, which is black with 3 white stripes: on the ground.

Fig. 659
Sergiolus variegatus (Emerton).

Family 6. PHOLCIDAE.

Eyes either 6 or 8 in number; legs very long, with 3 claws on each of the 3 hinder pairs: 6 American genera.

Pholcus Walckenaer. Three large eyes in a group on each side of the head and 2 smaller eyes in the middle; abdomen elongate; cephalothorax flat: 2 American species.

P. phalangioides (Fuesslin) (Fig. 660). Body 6 mm. long; longest legs 5 cm. long; color pale brown or gray: a common house spider both in America and in Europe, living in cellars, and making a large, flat, irregular web.

Fig. 660
Pholcus phalangioides—carrying its egg sac (Comstock).

Family 7. THERIDIIDAE.*

Usually small, light-colored spiders with a large round abdomen; eyes of about the same size, in 2 rows, with the end eyes near together and the middle eyes farther apart; outer margin of mandibles parallel (except on *Steatoda*); 3 claws on each leg: web often large, more or less irregular in form and loose in texture, and built in the corners of rooms, on fences and rocks, and between the branches of low trees and bushes, the spider usually staying in the web; about 300 American species.

Key to the genera of *Theridiidae* here described:

a_1 Abdomen smooth and shiny, the hairs being very short.....1. Steatoda
a_2 Abdomen hairy.
  b_1 The paired claws of the legs with a regular series of teeth almost to their tip.....2. Lathrodectus
  b_2 These claws with spreading teeth at their base.
    c_1 Abdomen with a high, pointed hump.....3. Argyrodes
    c_2 Abdomen not with a hump.
      d_1 Labium and sternum united.....4. Spintharus
      d_2 Labium not united with the sternum.
        e_1 Anterior row of eyes curved.....5. Theridula
        e_2 Anterior row of eyes straight.....6. Theridion

1. Steatoda Sundevall. Abdomen oval, smooth, and shiny; side eyes contiguous; those of the anterior row much larger than the middle

* See "New England Spiders of the Family Theridiidae," by J. H. Emerton, Trans. Conn. Acad., Vol. 6, p. 1, 1882.

pair; the 2 mandibles straight and parallel to each other: the web consists of a flat net held in place by numerous threads; 4 American species.

S. borealis (Hentz) (Fig. 661). Body about 6 mm. long and reddish-brown in color, the abdomen usually with a light stripe running around the front half and one in the middle: among stones or in fence corners; common.

Fig. 661
Steatoda borealis (Comstock).

2. **Lathrodectus** Walckenaer. Abdomen round and hairy; side eyes widely separated: 2 American species.

L. mactans (Fabricius) (Fig. 662). Body 12 mm. long and black, with a bright-red, hourglass-shaped spot underneath, and one or more red spots over the spinnerets and sometimes along the middle of the back; abdomen of male ovoid, with a row of red and white spots in the middle line and 4 pairs of red and white stripes on the sides: common; web large, with a funnel-shaped retreat in the middle.

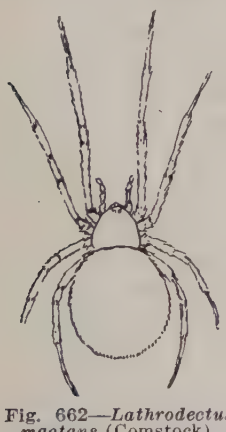

Fig. 662—*Lathrodectus mactans* (Comstock).

3. **Argyrodes** Simon. Abdomen with a high pointed hump: about 13 American species.

A. trigonum (Hentz) (Fig. 663). Body yellow, triangular in shape, 3 mm. long and 3 mm. high in the female; male with 2 horns in front of eyes: common; web between branches or leaves, or among the supporting strands of the webs of larger spiders.

4. **Spintharus** Hentz. Labium and sternum united; abdomen tapering to a blunt point over the spinnerets; side eyes close together: 1 American species.

S. flavidus Hentz. Body 4 mm. long; cephalothorax circular; upper surface of abdomen flat with a white stripe on each side and red and black in the middle: found on low plants; web unknown.

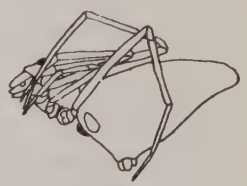

Fig. 663—*Argyrodes trigonum* (Emerton).

5. **Theridula** Emerton. Anterior row of eyes curved; first legs much longer than the fourth: 2 American species.

T. sphærula (Hentz). Body 2.5 mm. long; cephalothorax yellow or orange with a median black stripe; abdomen round and wider than long, and yellowish-gray in color with a greenish-white spot in the middle and a black spot at either side: common in bushes.

6. **Theridion** Walckenaer. Anterior row of eyes straight or nearly so; the 2 middle pairs of eyes of the same size, and equidistant from one another: about 40 American species.

T. tepidariorum Koch (Fig. 664). Body 6 mm. long, varying in color from whitish to black; cephalothorax usually light brown, the dark individuals with 6 transverse black marks on the abdomen: a cosmopolitan species and one of the commonest house spiders, being chiefly responsible for the webs in the corners; it breeds several times a year and the young and old are found at all seasons.

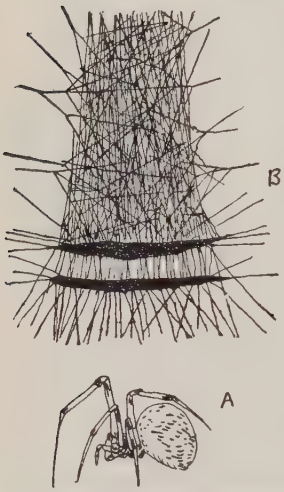

Fig. 664—*Theridion tepidariorum* (Emerton). A, the spider; B, its web.

T. frondeum Hentz. Body 3 mm. long, and white or bright yellow in color, with very variable black markings on the back, which may consist of 2 rows of spots or a median band: in bushes; common.

T. differens Emerton. Body about 3 mm. long; abdomen round, reddish-brown, with a red median stripe having white edges, which is bright in the female and obscure in the male; sternum orange: web on low plants, 5 or 6 inches in diameter.

T. murarium Em. Body about 4 mm. long; abdomen round, gray in color, with a reddish median stripe, white on the edges; sternum pale, with a black edge and a black median stripe: on low bushes.

Family 8. LINYPHIIDAE.

Small spiders with an elongate but high abdomen; mandibles with teeth around the terminal claw; epigynum and male appendages large and complex: web consists of a flat or curved sheet of silk supported above and below by great numbers of threads and found either in open woods or near the ground in grass and dead leaves, or in caves or cellars. The smaller species have the curious habit of flying in the late autumn. They come to the tops of fences and other elevated objects and cause their silk to be drawn out and floated aloft by the currents of air, until they are themselves lifted up and often blown long distances; about 95 American species.

Key to the genera of *Linyphiidae* here described:

a_1 Female with a terminal claw on the pedipalp.
  b_1 Hinder pair of median eyes not close together.....1. Linyphia
  b_2 Hinder pair of median eyes close together.....2. Lephthyphantes
a_2 No such terminal claw.
  b_1 No hard plate on the abdomen.....3. Erigone
  b_2 Abdomen covered by a hard plate.....4. Ceratinella

1. **Linyphia** Latreille. Legs with long spines along their sides; maxillae longer than wide; hinder pair of median eyes not near together; terminal segment of male pedipalp very large and complex: about 22 American species.

L. marginata Koch (Fig. 665). Body 4 mm. long; cephalothorax long and high in front; legs long and slender; color light yellow with median brown markings: web a dome 4 or 5 inches in diameter hung between plants or rocks, in the middle of which the spider lives; one of the commonest spiders in shady woods.

L. phrygiana Koch. Body 5 mm. long; color light yellow with a median black stripe which is serrated on both margins on the abdomen: web a large sheet, common in woods and near houses.

Fig. 665—Web of *Linyphia marginata* (Emerton).

2. **Lephthyphantes** Menge. Maxillae longer than wide; legs with long spines along their sides; hinder pair of median eyes near together; sternum heart-shaped; penultimate joint of the legs with a single spine: 4 American species.

Fig. 666
Lephthyphantes nebulosus (Comstock).

L. nebulosus (Sundevall) (Fig. 666). Length 4 mm.; color variable, usually light brownish-yellow with gray markings: common in cellars and damp places about houses, the web being flat.

3. **Erigone*** Savigny and Audouin. Pedipalp in the female without a claw; body rather narrow: very small spiders which live near the ground in grass, dead leaves, etc., in small webs; about 30 American species.

E. longipalpis (Sundevall). Body 2 mm. long, dark brown in color; cephalothorax smooth and shiny and sometimes bright orange in color; small pointed teeth along the sides of the thorax.

E. autumnalis Emerton. Body 1.2 mm. long, of a light color with a bright yellow head.

4. **Ceratinella** Emerton. Abdomen covered by a hard plate; pedipalp of female without a claw: 21 American species.

* See "A Catalogue of the Erigonae of North America," etc., by C. R. Crosby, Proc. Acad. Nat. Sci., Phila., 1905.

C. fissiceps (Cambridge). Body 1.5 mm.; abdomen round, and orange in color; head black around the eyes; the head of the male extends forwards, forming two humps: very common on small bushes.

Family 9. EPEIRIDAE.*

Round-web spiders. Usually large spiders with long legs and an abdomen which is rounded or ovoid and often provided with humps; often brightly colored; cephalothorax short, low in front with the eyes near the front edge and in 3 transverse groups, the 2 lateral pairs being close together and separated from the middle eyes; 3 terminal claws on each foot, usually with accessory spines also. The web is round and regular, with radiating spokes joined by cross threads (Fig. 667). The latter form 2 spirals, an inner spiral that begins in the center and winds outwards, covering usually less than a quarter of the finished web, and an outer spiral that begins at the edge and winds inwards, covering a large part of the web. The outer spiral is formed of a sticky thread which holds the insects flying against it. The spider usually tears down its web and builds a fresh one every night: this may be for the purpose of renewing the sticky thread, which gradually hardens. About 120 American species are known.

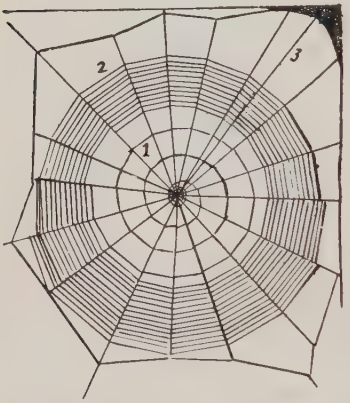

Fig. 667—An orb web (Emerton). 1, inner spiral; 2, outer spiral; 3, strand going to the nest.

Key to the genera of *Epeiridae* here described:

a_1 Abdomen not elongate, usually round or ovoid.
  b_1 Hinder row of eyes strongly curved; large brightly colored spiders. 1. Argiope
  b_2 Hinder row of eyes not curved or only slightly so.
    c_1 Thorax without a deep longitudinal furrow.
      d_1 Head and thorax separated by a deep transverse cervical groove. 2. Cyclosa
      d_2 No distinct cervical groove; thorax usually with a V-shaped furrow.
        e_1 Abdomen without spines.
          f_1 Web entire. 3. Epeira
          f_2 Web lacking a large segment. 4. Zilla
        e_2 Abdomen with prominent spines. 5. Acrosoma
    c_2 Thorax with a deep longitudinal furrow. 6. Mangora
a_2 Body elongate and light-colored.
  b_1 Groove between the spiracles curved markedly. 7. Tetragnatha
  b_2 This groove nearly straight. 8. Leucauge

* See "New England Spiders of the Family Epeiridae," by J. H. Emerton, Trans. Conn. Acad., Vol. 6, p. 295, 1884. "American Spiders," etc., by H. McCook, Vol. 3, p. 132, 1893.

1. Argiope Savigny and Audouin. Cephalothorax flat; head very small; eyes all alike, the second row strongly curved, first row straight or curved: about 5 American species.

A. aurantia Lucas (*A. riparia* Emerton) (Fig. 668). Body large and conspicuous, being often 25 mm. long, with long legs; abdomen black and 2 bright yellow or orange bands underneath; cephalothorax gray above and yellow underneath: the web is sometimes 2 feet in diameter and has a zigzag band of silk across the middle; the male has a small, irregular web nearby; in grass and bushes; in open fields, especially near water.

A. trifasciata (Forskal) (*A. transversa* Em.). Like the above, but a little smaller; abdomen white or light yellow, crossed by black lines: web often in marshes.

2. Cyclosa Menge. Head and thorax of the female separated by a deep transverse groove: 5 American species.

C. conica (Pallas). Abdomen with a blunt conical lump at its hinder end; length 6 mm.; color gray: the web has a band of silk across it in which the spider fastens sticks and rubbish, and is protected by its resemblance to them.

3. Epeira Walckenaer (*Araneus* Simon). Thorax without a transverse furrow; the 2 rows of eyes straight or nearly so, 4 eyes being median in position and a pair at some distance from them on each side: about 57 American species.

Fig. 668—*Argiope aurantia* (Emerton).

E. foliata Koch (*E. strix* Hentz). Length 8 mm.; color brown, with a broad scalloped stripe on the back of the abdomen; cephalothorax with 3 longitudinal stripes: common all over the country around houses and on bushes and fences.

E. angulata (Clerck). Length 12 mm.; color dark brown, with a yellow stripe on the sternum and yellow spots on the under side of the abdomen; anterior end of abdomen with a pair of humps and a yellow spot: common among trees.

E. cavatica Keyserling (*E. cinerea* Emerton). Length 18 mm.; color dirty white with grayish markings; long white hairs scattered over the body; abdomen with 2 small humps in front: common about houses and barns in New England.

E. globosa Keys. Length 6 mm.; abdomen round and large, and yellowish in color, with 4 large, square, whitish or pinkish spots on the anterior and 3 or 4 pairs of black spots on the posterior portion: web large, with one segment left open or partly open and with a thread running from its center to the large nest; common.

E. prompta Hentz. Body 6 mm. long and gray in color, with variable black and yellow markings on the back: common in low bushes.

Fig. 669—*Epeira gigas* (Comstock.)

E. gigas Leach (*E. insularis* Hentz) (Fig. 669). Length 16 mm.; abdomen large and ovoid, and bright yellow or orange in color with brown or purple markings; cephalothorax dull yellow: in bushes and low trees; the spider makes a nest of leaves in which it stays, holding a thread which runs to the center of the web; in all parts of the country.

E. domiciliorum Hentz. Length 8 mm.; color light yellow with brown markings, sometimes with red spots on the abdomen; cephalothorax with 3 faint stripes; sternum bright yellow in the middle: in bushes and on fences.

E. trifolium Hentz. Length 20 mm.; abdomen large and round, light or dark brown in color, with white spots; legs with conspicuous black or reddish rings; cephalothorax white, with 3 black stripes: in bushes and tall weeds; the spider has a nest of leaves joined with the center of the web by a thread like *E. gigas*.

4. **Zilla** Koch. The 2 middle pairs of eyes near the 2 lateral pairs; the hinder row of eyes somewhat longer than the forward row; abdomen elliptical: about 4 American species.

Z. atrica (Koch). Length 7 mm., with a large, somewhat flattened abdomen; color gray, with a broad scalloped stripe on the abdomen: a segment of the web is without cross threads, opposite which a thread runs from the center of the web to the nest; about houses.

Fig. 670 *Acrosoma spinea* (Comstock).

5. **Acrosoma** Perty (*Micrathena* Sundevall). Small brightly colored spiders with a flattened abdomen which is extended backwards and furnished with several pairs of pointed projections: the web often has a hole in the center; 4 American species.

A. spinea Hentz (Fig. 670). Length 5 mm.; abdomen narrow in front and with 2 long spreading points behind; 2 pairs of smaller spines also present; color white or yellow with black spots; spines red and black.

6. Mangora Hentz. Thorax elevated behind and with a deep median furrow; second row of eyes straight or curved backwards: 3 American species.

M. gibberosa (Hentz). Body 5 mm. long and light yellow or gray in color, the abdomen with 2 parallel black lines on the hinder half, and a number of small black spots: web with about 60 radial spokes and the cross spirals very close together.

7. Tetragnatha Latreille. Slender, light-colored spiders living in their webs in the long grass in meadows and near water; mandibles large, extending forward and divergent: about 4 American species.

T. extensa (L.). Length 6 mm., with abdomen twice as long as the cephalothorax; color yellowish-brown or gray.

8. Leucauge White. Elongated spiders with the lateral eyes near together and nearly equal in size; 3 claws on the feet: 2 American species.

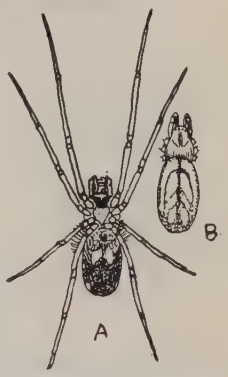

Fig. 671 — *Leucauge hortorum* (Emerton). A, ventral view of female; B, dorsal view.

L. hortorum (Hentz) (Fig. 671). Body 6 mm. long; cephalothorax and legs bright green; abdomen silvery white above, with a dark line through the middle with red and yellow spots: web large, with a zigzag band of silk across the center.

Family 10. THOMISIDAE.*

The crab spiders. Short, flat spiders, usually widened behind, with a sidewise gait and a crab-like appearance; the first and second pairs of legs much longer than the others and extended at right angles to the body; 2 claws on each foot; eyes in two curved rows: about 114 American species, which are found on walls, flowers, and similar places; they do not make a web.

Key to the genera of *Thomisidae* here described:

a_1 Body and legs crab-like.
  b_1 Lateral eyes on tubercles.
    c_1 Two eye tubercles on each side.
      d_1 Hinder eye tubercle the larger.....1. Tmarus
      d_2 Front eye tubercle the larger.....3. Xysticus
    c_2 A single eye tubercle on each side.....2. Misumena
  b_2 No eye tubercle present.
    c_1 Labium much longer than wide.....4. Philodromus
    c_2 Labium not longer than wide.....5. Ebo
a_2 Body long and slender, not crab-like.....6. Tibellus

* See "New England Spiders of the Family Thomisidae," by J. H. Emerton, Trans. Conn. Acad., Vol. 8, p. 359, 1892.

1. **Tmarus** Simon. Front of head truncate; hinder row of eyes much longer than the forward; lateral eye on each side being raised on tubercles, the hinder tubercle on each side being much larger than the forward one; abdomen high and pointed behind: 5 American species.

T. caudatus (Hentz) (Fig. 672). Length 6 mm.; color mottled gray; abdomen highest at hinder end, which forms a conical knob: on trees and fences; common.

Fig. 672
Tmarus caudatus (Emerton).

2. **Misumena** Latreille. Large, brightly colored or white spiders living in flowers, the colors of which they often mimic; the 2 lateral eyes on each side on a single tubercle: about 20 American species.

M. vatia Thorell. Length 12 mm.; color white or yellow, sometimes with a crimson spot on each side of the abdomen and another between the eyes; sides of thorax yellowish: common.

M. asperata (Hentz). Length 6 mm.; color pale yellow or white, with dull red markings on the abdomen and a brown stripe on each side of the thorax; scattered stiff hairs present; common.

3. **Xysticus** Koch. Each lateral eye on a tubercle, the forward one being the larger; median ocular area as wide or wider in front than behind: 40 American species, which live under bark, stones, and leaves.

Fig. 673

X. triguttatus Keyserling. Length 5 mm.; females straw-colored or yellow, with black spots on the thorax and front of the abdomen and 3 broken transverse stripes behind; male with a thorax which is dark brown at the sides and lighter in the middle, and an abdomen banded with black and white: very common in grass and low bushes.

Fig. 674

X. versicolor (Keyserling) (Fig. 673). Length 7 mm.; body flattened, mottled black and gray in color: common on trees, fences, etc.

Fig. 673—*Xysticus versicolor* (Emerton). Fig. 674—*Philodromus vulgaris* (Emerton).

4. **Philodromus** Walckenaer. Abdomen bluntly pointed behind and flat; legs long, the second pair being the longest; labium much longer than wide: 24 American species.

P. vulgaris (Hentz) (Fig. 674). Length 6 mm.; legs very long, spreading an inch or more; color mottled gray with a median marking on the abdomen: on fences and walls.

5. **Ebo** Keyserling. Labium not longer than wide; second pair of legs twice as long as any of the others; median eyes larger than the lateral ones; hinder row nearly straight: 3 American species.

E. latithorax Keys. Length 3 mm.; color gray and white, with black spots; body very wide; head narrow in front.

6. **Tibellus** Simon. Body long and slender, the legs projecting ahead and behind and not sideways; both rows of eyes curved: 2 American species.

T. oblongus (Walckenaer) (*T. duttonii* Emerton) (Fig. 675). Length 12 mm.; width 2 mm.; color gray or yellow, with dark longitudinal bands and a pair of black spots on the hinder part of the abdomen: very common on bushes and grass.

Fig. 675 *Tibellus oblongus* (Emerton).

Family 11. CLUBIONIDAE.

Light-colored spiders usually without color markings; upper row of eyes longer and the eyes usually larger than the under row; mandibles of females swollen at the base: the animals live in flat tubular webs in rolled-up leaves or on plants and under bark and stones; about 95 American species.

Key to the genera of *Clubionidae* here described:

a_1 Posterior spinnerets with a very distinct, conical terminal segment.
  b_1 Labium much longer than wide and extending beyond the middle of the maxillae ..... 1. Clubiona
  b_2 Labium about as long as wide or less so, and not extending beyond the middle of the maxillae; sternum extending between the hind legs. 2. Phrurolithus
a_2 Posterior spinnerets with a very short and frequently indistinct terminal segment.
  b_1 Cervical groove present.
    c_1 Legs spiny ..... 3. Castianeira
    c_2 Legs not spiny ..... 5. Trachelas
  b_2 Cervical groove absent ..... 4. Micaria

Fig. 676—*Clubiona obesa* (Emerton).

1. Clubiona Latreille. Hinder legs longer than forward; spinnerets distinctly segmented; labium longer than wide; mandible long; eyes very near the front margin of head: about 20 American species.

C. obesa Hentz (*C. crassipalpis* Keyserling) (Fig. 676). Length 6 mm.; pale in color, without markings; mandibles and ends of male pedipalps dark; eyes in each row equidistant, the hinder row being the longer: common.

2. Phrurolithus Koch. Each terminal claw with 6 to 10 spatulate hairs; sternum broad and extending between the hind legs: 8 American species.

P. alarius (Hentz) (Fig. 677). Length 3 mm.; cephalothorax light yellowish, with a black line on each edge; abdomen covered with iridescent scales which change in color from grayish-green to pink: a very active spider living among stones on the ground.

Fig. 677
Phrurolithus alarius (Emerton).

3. **Castianeira** Keyserling. Cervical groove present; anterior median eyes not close to the margin of the head; legs spiny: about 18 American species.

C. descripta (Hentz) (*C. crocata* Emerton). Length 8 mm.; body black, with a bright red spot on the end of the abdomen; ends of legs yellow: among stones in dry, open places; its egg case is a small parchment-like disc attached to a rock.

4. **Micaria** Westring. Body covered with scale-like hairs; last segment of the hind spinnerets very short, frequently indistinct, with an oblique groove; no cervical groove: 13 American species.

M. aurata (Hentz). Body resembles an ant in size and color; length 6 mm.; color light brown, varying to bright yellow and orange: eastern states.

5. **Trachelas** Koch. Posterior row of eyes curved forward; legs without or with few spines, dorsal groove present: about 5 American species.

T. tranquilla Hentz (*T. ruber* Keyserling). Length 8 mm.; cephalothorax wide; abdomen ovoid; color deep orange brown, the abdomen much lighter than the cephalothorax: under stones and leaves.

Family 12. AGELENIDAE.

The funnel-web spiders. Cephalothorax large, and often narrow in front and broad behind; cervical groove present; hind spinnerets very long and 2-jointed; mandibles large; 3 terminal claws on the feet: mostly large spiders which make a flat web on the grass and in the corners in barns and cellars, in the middle of which is a funnel-shaped tube forming the spider's retreat; about 50 American species.

Key to the genera of *Agelenidae* here described:

a_1 Spinnerets not in a transverse line.
  b_1 Both rows of eyes strongly curved backward.....1. Agelena
  b_2 Both rows of eyes not or but slightly curved backward.
    c_1 Anterior median eyes much smaller than the lateral.....2. Coras
    c_2 Anterior median eyes either equal in size or smaller than the lateral. 3. Tegenaria
a_2 Spinnerets in a straight or curved line.....4. Hahnia

1. **Agelena** Walckenaer. Both rows of eyes strongly curved backwards so that the anterior median and the posterior lateral are in a straight line; terminal segment of the hind spinnerets at least as long as the basal segment: about 4 American species.

A. nævia Walck. Grass spider (Fig. 678). Body 18 mm. long or less, and yellowish brown, or black in color, with gray or dark markings and spots on the abdomen and broad longitudinal stripes on the cephalothorax, and covered with fine hairs: the very common spider which makes flat webs in the grass which are conspicuous when covered by dew; also in houses.

Fig. 678—*Agelena nævia (Emerton)*

2. **Coras** Simon. Rows of eyes not curved or but slightly so; anterior median eyes much larger than the lateral: 1 species.

C. medicinalis (Hentz) (Fig. 679). Body 12 mm. long, light yellowish-brown in color and covered with gray hairs; abdomen large and oval and marked with gray spots of irregular shape: in woods among rocks and under loose bark, the web is not flat, but is usually curved in several places.

Fig. 679—*Coras medicinalis* (Emerton).

3. **Tegenaria** Latreille. Eyes all of the same size, both rows curved, the forward row but slightly; legs long and slender: about 7 American species.

T. derhami (Scopoli). Body 10 mm. long, pale in color, with gray stripes and spots; first and fourth pairs of legs the longest: in cellars, barns, etc.; the web often forms a thick shelf in the corner; very common, having been imported from Europe, it and *Theridion tepidariorum* making most of the corner webs in cellars.

Fig. 680 *Hahnia agilis*, ventral aspect (Emerton).

4. **Hahnia** Koch. Spinnerets extend across the abdomen in a straight or curved line; anterior middle eyes smaller than the lateral: about 6 American species.

H. agilis Keyserling (*H. bimaculata* Emerton) (Fig. 680). Length 3 mm.; cephalothorax bright orange brown in color and the legs and abdomen pale yellowish with gray markings: common under stones and leaves or among grass and moss.

Family 13. PISAURIDAE.

Eyes in 3 rows; cocoon carried in the mandibles of the female; cephalothorax broad and flat: ground spiders of large size similar to the *Lycosidae;* about 18 American species.

1. Pisaurina Simon. Anterior row with 4 eyes of same size and straight; area of the middle eyes longer than broad: 3 American species.

P. undata (Walckenaer). Length 13 mm.; color light brownish-yellow, with a wide, median, dark band edged with white running the length of the body; abdomen long and narrower than the cephalothorax: common in bushes; no web is made until the young are ready to hatch, when the female builds a small web about the cocoon in which the young may live.

2. Dolomedes Latreille. Area of the middle eyes as broad or broader than long; anterior row of eyes curved forward: 7 American species.

D. fontanus Emerton (*D. tenebrosus* Em.) (Fig. 681). Length 20 mm., with legs spreading 10 cm.; color gray; cephalothorax larger than the abdomen and with light bands on the side; abdomen with dark cross lines: common on the ground in low bushes near water with habits like *P. undata.*

D. sexpunctatus Hentz. Length 15 mm.; color dark greenish-gray, with a whitish line on each side of the length of the body; abdomen larger than the cephalothorax; sternum with 6 dark spots: common under stones near the water on which it runs readily.

Fig. 681
Dolomedes fontanus (Emerton).

Family 14. LYCOSIDAE.*

Wolf spiders. Large, active spiders which live on or near the ground; eyes usually in 3 rows; in the front row are 4 small eyes and back of these 2 pairs of large eyes; cephalothorax high and prismatic; feet with 3 claws, the small one surrounded by hairs: no web built, but many species line their retreats with silk; the cocoon is attached to the spinnerets and the young spiders are carried for a short time on the mother's back; about 114 American species.

Key to the genera of *Lycosidae* here described:

a_1 Labium longer than broad.
  b_1 Posterior spinnerets not longer than the anterior or but slightly so.
    c_1 Cephalothorax highest in the cephalic region.....1. Lycosa
    c_2 Cephalothorax highest in the middle.....2. Trochosa
  b_2 Posterior spinnerets half again as long as the anterior.....4. Pirata
a_2 Labium at least as broad as long.....3. Pardosa

* See "New England Lycosidae," by J. H. Emerton, Trans. Conn. Acad., Vol. 6, p. 481, 1885. "Canadian Spiders," by same, ibid., Vol. 9, 1895. "Descriptions of North American Araneae of the Families Lycosidae and Pisauridae," by T. H. Montgomery, Proc. Acad. Nat. Sci., Phila., 1904, p. 261.

1. Lycosa Latreille. Head very high and with sloping sides; labium longer than broad; hinder 2 pairs of eyes not on the margin of the head; legs usually long and with long spines: about 50 American species.

L. helluo Walckenaer (*L. nidicola* Emerton). Length 18 mm.; longest legs 25 mm.; color dull yellow or greenish-brown, with 3 narrow yellow stripes on the cephalothorax and a pointed stripe on the front half of the abdomen: common under stones in moist meadows and woods; the female is seen with her cocoon in early summer.

L. avida Walck. (*L. communis* Em.) (Fig. 682). Length 10 mm.; longest legs 18 mm.; color from gray to black, with 3 light stripes on the cephalothorax and a pair of broad median stripes meeting behind on the abdomen: common in pastures, the female is carrying her cocoon in early summer.

Fig. 682—*Lycosa avida* (Emerton).

L. rabida Walck. (*L. scutulata* Hentz). Length 13 mm.; longest legs 26 mm.; cephalothorax dark gray in color, with 3 light stripes; abdomen with a wide median stripe and several light and dark lines at each side.

L. carolinensis Walck. One of our largest spiders, sometimes over 35 mm. long with legs spreading 75 mm.; body covered with thick hair and brown above and black beneath in color: on the ground or in its hole, a deep cylindrical pit, in which the eggs are hidden.

L. pikei Marx (*L. arenicola* Scudder). Sand spiders. Length 18 mm.; color of male gray or sand color, with a spot in the middle of the abdomen, female gray or slate color, with a broad, serrate band on the abdomen: the female lives in a hole 10 inches deep, around the mouth of which is sometimes a low turret of sticks.

2. Trochosa Koch. Legs quite short; first row of eyes about as long as the second, which is not quite as long as the third row: 4 American species.

T. cinerea (Fabricius). Length 12 mm.; body gray or sand color with small spots: common on beaches and in sandy fields.

3. Pardosa Koch. Slender spiders with long legs; labium at least as broad as long; front row of eyes shorter than the second; second and third pair of eyes large and near the lateral margin of the head: 30 American species.

P. nigropalpis Emerton. Length 6 mm.; color black with a wide, irregular median area; pedipalps of male black: on the ground.

4. **Pirata** Sundevall. Labium longer than broad; first row of eyes as broad as the second: beneath stones and in the grass near the water over the surface of which they may freely run; 16 American species.

P. piratica (Clerck) (*P. marxi* Stone) (Fig. 683). Length 6 mm.; color pale yellow with gray or black markings; eyes of the second row about half their diameter apart.

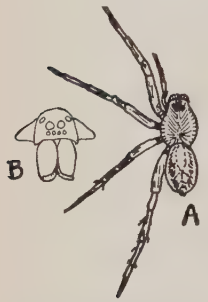

Fig. 683 — *Pirata piratica* (Emerton). A, dorsal aspect; B, front view, showing the eyes.

Family 15. ATTIDAE.*

Jumping spiders. Eyes in 3 rows, the front row usually curved and composed of 4 large eyes, the second row of 2 very small eyes, the third row far back on the head and composed of 2 large eyes which are usually turned a little backward; cephalothorax large and wide in front; legs strong and short and with 2 terminal claws on each; body covered with hairs or scales: no web made, but some species make silk bag-like retreats on plants and under stones; the spiders run and jump sidewards and backwards as well as forwards; about 213 American species.

Key to the genera of *Attidae* here described:

a_1 Body not shaped like an ant.
  b_1 Abdomen not longer than the hind legs.
    c_1 Body not noticeably flattened.
      d_1 Front row of eyes not touching one another.
        e_1 Eye area broader than long, body short and wide.....1. Attus
        e_2 Eye area not broader than long.
          f_1 Eye area somewhat wider behind than in front.....2. Phidippus
          f_2 Eye area quadrangular.....3. Dendryphantes
      d_2 Eyes of front row touch one another.....4. Salticus
    c_2 Body noticeably flattened.....5. Marpissa
  b_2 Abdomen longer than hind legs.....6. Hyctia
a_2 Body like an ant in shape.....7. Synemosyna

1. **Attus** Walckenaer. Eye area broader than long; first leg with 2 rows of spines on distal half; third leg shorter than the fourth: about 6 American species.

A. palustris Peckham (Fig. 684). Length 6 mm.; color brown or gray, with a median white line on the cephalothorax; abdomen with white spots and markings: on plants, with nests among the leaves.

Fig. 684—*Attus palustris* (Emerton).

2. **Phidippus** Koch. Cephalothorax high; eye area wider behind than in front; first leg thick and long; third leg shorter than the fourth: about 50 American species.

* See "Attidae of North America," by G. W. and E. G. Peckham, Trans. Wis. Acad. Sci., Vol. 7, 1888. "New England Spiders of the Family Attidae," by J. H. Emerton, Trans. Conn. Acad., Vol. 6, p. 220, 1891.

P. podagrosus Hentz (*P. multiformis* Emerton) (Fig. 685). Length 8 mm.; males black, with white and orange markings on the abdomen; female brown, mixed with black, white, and yellow, there being 3 or 4 pairs of white spots on the abdomen of both sexes: very common on plants, with bag-like nests among the leaves.

Fig. 685—*Phidippus podagrosus* (Emerton).

P. audax Hentz. Length 12 mm.; color black, with 3 large, white spots on the abdomen and several smaller ones: common under stones and sticks where it has a nest.

3. **Dendryphantes** Koch. Second and third rows of eyes both small; eye area forms a quadrangle; cephalothorax rather high and short; third leg shorter than fourth: about 22 American species.

Fig. 686—*Salticus scenicus* (Emerton).

D. capitatus (Hentz) (*D. æstivalis* Peckham). Length 5 mm.; legs ringed; color variable, in male dark brown with a white stripe on each side, in female light yellow with 4 pairs of brown spots on the abdomen: common on bushes.

4. **Salticus** Latreille (*Epiblemum* Hentz). Eyes of front row touching one another; mandibles of male very long and projecting in front of head: 4 American species.

S. scenicus (Clerck) (Fig. 686). Length 6 mm.; gray in color with 2 pairs of oblique, white spots on the abdomen and 2 white spots on the cephalothorax: one of the commonest jumping spiders, on houses and fences; also in Europe.

5. **Marpissa** Koch (*Marptusa* Thorell). Cephalothorax and abdomen both widened in the middle and of about the same size; legs long and thick: 6 American species.

M. familiaris (Hentz). Length 12 mm.; body flattened, gray in color; cephalothorax with a dark brown band along each side; abdomen with a broad, irregular, yellowish-white median band: common on houses and fences.

Fig. 687 *Hyctia pikei* (Emerton).

6. **Hyctia** Simon. Abdomen long and slender and narrower than the cephalothorax; front legs much larger than the others: 2 American species.

H. pikei Peckham (Fig. 687). Body 8 mm. long and very slender, with the abdomen twice as long as the cephalothorax and longer than the hind legs; abdomen with a very broad, black stripe having 3 notches on each side; rest of the body whitish; front legs brown, others white: common on sand and grass, on which it often lies with the legs parallel to the body, so that it would be seen with difficulty.

7. SYNEMOSYNA Hentz. Cephalothorax and abdomen each with a deep dorsal depression; middle of the body slender, front middle eyes large, the rest small: 1 species.

S. formica Hentz. Ant-like spider (Fig. 688). Body 6 mm. long and very slender; cephalothorax narrowed behind and the abdomen in front, and each has a deep dorsal depression in the middle; color black with yellowish markings: the spider resembles an ant in shape and method of walking.

Fig. 688
Synemosyna formica (Emerton).

ORDER 8. ACARINA.*

The mites. Small arachnids, in which cephalothorax and abdomen are unsegmented and so joined that the short, thick body is more or less ovoid or globose in shape. In some forms a suture separates the forward part of the body with two pairs of legs from the hinder part with the two hinder pairs; in a few also the abdomen is elongated and annulated, although not segmented. The six pairs of appendages are well developed and consist of the mandibles and pedipalps and four pairs of legs, except in the *Eriophyidae,* which have but two pairs. The mandibles may be chelate or formed for piercing and sucking. The pedipalps are usually more or less leg-like, with five joints or less, and in some forms they are chelate or subchelate; the basal joints may form plates called the maxillae, or they may unite to form a lip or labium. Accessory mouth parts are often present, as a hypostome or under lip and tongue, and an upper lip or epistome; the latter may be united with the lip below to form a tube called the rostrum, from which the mandibles protrude. The legs are usually 5-jointed and end each with two claws. The external surface of the body is more or less covered with tactile hairs or with scales. Eyes are either present or absent. The

* See "A Treatise on the Acarina or Mites," by Nathan Banks, Proc. U. S. Nat. Mus., Vol. 28, p. 1, 1905. "A Catalogue of the Acarina or Mites of the United States," by Nathan Banks, same, Vol. 32, p. 595, 1907. "The Life History and Bionomics of Some North American Ticks," by W. A. Hooker and others, Bull. 106, Bur. Ent., U. S. Dept. Ag., 1912. "New Mites," by H. E. Ewing, Bull. Am. Mus. Nat. Hist., Vol. 32, p. 93, 1913. "The Acarina," by N. Banks, Rep. 108, Bur. Ent., 1915.

anus is at the hinder end of the body; the genital pore lies in front of it.

The internal structure is characterized by its compactness. The digestive tract is well developed. Two Malpighian tubules, if any, are present. Many forms have no special respiratory system; others have tracheae, which open to the outside through a pair of spiracles situated either at the base of the mandibles or near the hind legs.

The nerve ganglia are all united into a single mass, which is pierced by the œsophagus. Mites are unisexual animals. The young animal is usually born as a larva with six legs (Fig. 713, C); after feeding awhile it passes into a resting stage, from which it emerges as a so-called nymph, which has eight legs but no genital orifice; at the end of the nymphal stage it again becomes quiescent and develops into the adult. In some forms the development is abbreviated and the young animal is born as a nymph, or even as an adult. The six-legged larval stage has been observed in certain species to be preceded by an eight-legged embryonic stage, which seems to indicate that the former condition is not a primitive one.

Most mites are land animals and about half the species are parasitic, many, as the itch and mange mites and the ticks, being among the most troublesome and even dangerous parasites infecting man and his domestic animals. Many are parasitic on insects, especially on beetles and ants. A few are entoparasites, *Halarachne,* living in the trachea of seals, and *Pneumonyssus,* in the lungs of a monkey. The non-parasitic forms eat small animals, including each other, and also decaying plant or animal matter, and are found on plants and the ground, under bark or dead leaves, while some form galls on plants. The *Hydrachnidae* and *Halacaridae* are aquatic, the former living in fresh and the latter in salt water. They are, however, very little modified for swimming, and possess no gills. The order contains about 3,000 species, about 500 being known in this country. These are grouped in about 26 families.

Key to the families of *Acarina* here described:

a_1 Body elongate and worm-like, the hinder part ringed; animals minute.
  b_1 Gall mites; but 4 legs present.....1. Eriophyidae
  b_2 Eight legs present; mammalian parasites.....2. Demodicidae
a_2 Body not worm-like.
  b_1 No spiracles or trachea present; minute mites.
    c_1 On mammals or birds.
      d_1 Itch and mange mites; parasites in the skin of mammals..3. Sarcoptidae
      d_2 Bird mites; among the feathers of birds.....4. Analgesidae
    c_2 In fruit, grain, cheese, etc., and in certain plants.....5. Tyroglyphidae
  b_2 Spiracles and tracheae usually present.
    c_1 Horny mites; a pair of usually club-shaped bristles on cephalothorax.
      6. Oribatidae
    c_2 No such bristles.

d_1 Each spiracle in a stigmal plate (Fig. 700, C) near the fourth pair of legs.
e_1 Stigmal plate in front of fourth leg.
f_1 Not on birds (except the genus *Dermanyssus*) ..... 7. GAMASIDAE
f_2 Parasitic on birds ..... 8. ARGASIDAE
e_2 Stigmal plate behind fourth leg ..... 9. IXODIDAE
d_2 Spiracles not in stigmal plates, but at the base of the mandibles or near the fourth pair of legs.
e_1 Aquatic mites.
f_1 Fresh-water mites ..... 10. HYDRACHNIDAE
f_2 Salt-water mites ..... 11. HALACARIDAE
e_2 Not aquatic.
f_1 Mandibles long and snout-like ..... 12. BDELLIDAE
f_2 Mandibles not so; body often red.
g_1 Mandibles chelate; eyes stalked ..... 13. TROMBIDIIDAE
g_2 Mandibles piercing; eyes sessile.
h_1 Mid-dorsal line present; not web-spinning .... 14. RHYNCHOLOPHIDAE
h_2 No mid-dorsal line; web-spinning ..... 15. TETRANYCHIDAE

FAMILY 1. ERIOPHYIDAE.* (PHYTOPTIDAE.)

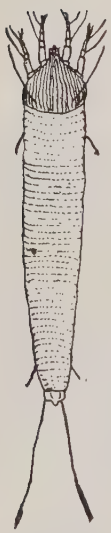

Fig. 689 *Eriophyes vitis* (Banks).

Gall mites. Body minute and worm-like, the hinder part being greatly prolonged and ringed; eyes and tracheae absent; but 2 pairs of legs present, the hinder 2 parts being represented by wart-like projections or by hairs; pedipalps leg-like and 3-jointed, and holding between them the rostrum, in which lie the needle-like mandibles; anus at the hinder end. The animals feed on plant juices and are the cause of galls, fuzzy spots, and other deformed structures on plants. The gall always has an opening (differing in this respect from those of the *Hymenoptera* and the *Diptera,* but not the *Homoptera*) and vary much in form among the different species. A fuzzy spot or erineum is a dense mass of twisted hairs, among which the mites live. Some of these mites live in buds and kill them, others cause the edge or surface of a leaf to curl or fold, while still others produce abnormal growths on twigs. The family contains about 227 species, 27 species being American.

ERIOPHYES von Siebold (*Phytoptus* Dujardin). Number of rings about the same on upper and under sides of the body: about 144 species, 22 American.

E. pyri (Pagenstecker). Pear-leaf blister. Length .19 mm.; width .05 mm.: causes round, red spots on pear leaves, the opening being on the under side; the animals winter in the leaf buds.

* See "The Phytopti and Other Injurious Plant Mites," by H. Garman, Twelfth Rep. of St. Ent. Illinois, 1883, p. 23. "Eriophyidae," by A. Nalepa, Das Tierreich, 1898. "Galls and Insects Producing Them," by M. S. Cook, Ohio Nat., Vol. 2, p. 263; Vol. 3, p. 419; and Vol. 4, p. 125, 1902-04. "The Eriophyidae, Part I, The Apple and Pear Mites," by P. J. Parrott, H. E. Hodgkins and W. J. Schoener, Bull. 283, N. Y. Ag. Ex. St., 1906.

E. vitis (Landois) (Fig. 689). Produces an erineum on the under side of grape leaves, which causes a swelling on the upper side; length .16 mm.; width .032 mm.

E. quadripes (Shimer). Produces round galls on leaves of the soft maple.

Family 2. DEMODICIDAE.*

Body minute and worm-like, the hinder part being greatly prolonged and ringed; eyes and tracheae absent; 4 pairs of 3-jointed legs; pedipalps close against the rostrum; anus just back of the hind legs: 1 genus with about 5 species.

Fig. 690 *Demodex folliculorum* (Banks).

Demodex Owen. With the characters given above: several species, which live in sebaceous glands and hair follicles of man and the domestic animals.

D. folliculorum Simon (Fig. 690). Length .4 mm. or less; width .05 mm.: in the skin of the human face, supposed to be the cause of "blackheads"; also in cattle and hogs.

D. bovis Stiles. Length .25 mm.; width .064 mm.: in the skin of cattle, causing swellings of the size of a pea in the hide.

Family 3. SARCOPTIDAE.*

Itch mites. Body minute, globular, or ovoid in shape, finely striated on the surface and with a few long bristles; eyes and tracheae absent; legs short, each ending in 1 or 2 claws or a stalked or sessile sucker or a

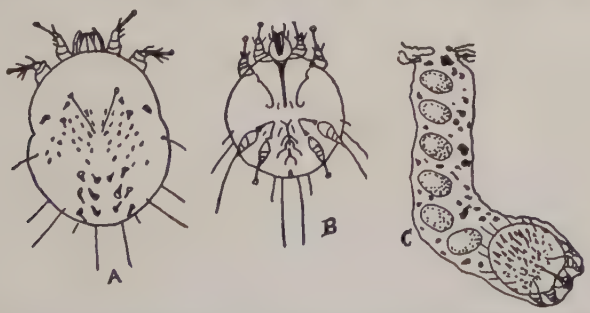

Fig. 691—*Sarcoptes scabiei* (Banks). A, dorsal aspect of female; B, ventral aspect of male; C, a mite in its burrow.

bristle; pedipalps close against the rostrum; mandibles usually chelate: in the skin of mammals and a few birds, causing itch and mange. The female burrows through the skin, feeding on the tissues, and leaving a row of eggs behind her, and finally dies at the end of her burrow. The

* See "Demodicidae et Sarcoptidae," Das Tierreich, 1899.

young female on being fertilized starts a burrow and thus a host becomes infested in patches. About 100 species, 13 species being American.

1. **Sarcoptes** Latreille. The first two pairs of legs end with stalked suckers and in the male the fourth pair also; the others end each with a long bristle; mandibles chelate: in mammals, burrowing in the skin; about 14 species, 6 American.

Fig. 692
Psoroptes ovis—female (Banks).

S. scabiei (DeGeer) (*S. hominis* Hering). Itch mite (Fig. 691). Length of female .45 mm.; width .35 mm.; male half as large; egg .14 mm. long: causes itch in man and mange in hogs.

S. canis Gerlach. Mange mite. Length of female .48 mm.; width .35 mm.; egg .17 mm. long: causes mange in dogs, also in man.

S. cati Hering. Mange mite. Length of female .25 mm.; width .2 mm.; egg .1 mm. long: causes mange in cats.

2. **Psoroptes** Gervais. Mandibles adapted for piercing and not burrowing; stalks of leg suckers jointed: on the surface of the skin of mammals, where they suck blood; 5 species.

P. ovis Hering. Scab mite (Fig. 692). Length of female .60 mm.; width .40 mm.; egg .2 mm. long: on sheep, cattle, and horses, causing scab; the eggs hatch in 2 or 3 days and the young mature in 15 days; the females live several weeks, laying numerous eggs; an infection thus spreads very rapidly and may cause the death of the host; common in the west.

Fig. 693
Cnemidocoptes mutans (Banks).

3. **Chorioptes** Gervais. Females with suckers on the fourth pair of legs: on the surface of the skin of mammals, being restricted to certain parts of the animal; 2 species.

C. communis Zürn. Length of female .42 mm.; width .27 mm.: causes local inflammation in the ears of dogs, cats, and rabbits.

4. **Cnemidocoptes** Fürst. Female without suckers on any of the legs; mandibles chelate: on birds; 2 American species.

C. mutans Robin (Fig. 693). Length of female .45 mm.; width .35 mm.: the itch mite of fowls, causing scaly leg, but also appearing among the feathers.

Family 4. ANALGESIDAE. (Dermaleichidae.)

Bird mites. Minute mites with an elongated body, a transversely striated integument and often a transverse suture between the front 2

and the back 2 pairs of legs; mandibles usually chelate and beneath an epistome; legs with 5 joints and with a terminal sucker; in some genera the male has a pair of clasping suckers and copulatory legs; abdomen often bilobed behind: 31 genera and 400 species, which live upon birds, feeding on the feathers, epidermal scales, etc., and usually not parasites; 24 American species.

1. **Analges** Nitzsch (*Dermaleichus* Koch). Body elongate, with the hinder end rounded or pointed, and never deeply bilobed; spines on the first pair of legs; third pair of legs of male larger than the others and ending with claws and not suckers; basal joint of first and second leg with a backward projection: on singing birds; 23 species, American.

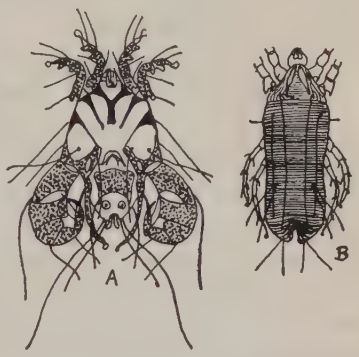

Fig. 694—*Analges passerinus* (Banks). A, male; B, female.

A. passerinus (L.) (Fig. 694). Length .45 mm.; third pair of legs of male enormously enlarged and used as claspers: a European mite, found on several species of American birds.

2. **Megninia** Berlese. Third pair of legs much larger than the fourth, with long spines on the terminal joint; end of abdomen deeply bilobed in male: 42 species, 6 American.

M. columbae Buchholz. Length .33 mm.; each abdominal lobe in male with 2 long and several small bristles; space between the lobes filled in by a membrane: on domestic pigeons and other birds.

Family 5. TYROGLYPHIDAE.*

Minute mites with an elongated body and a smooth integument; legs alike in the two sexes; mandibles usually chelate; eyes and tracheae absent; pedipalps close against the mouth parts; young born with 3 pairs of legs, in most forms passing through a stage called the hypopus, in which it has 8 legs, but no mouth and no distinct mouth parts, but with suckers on the under surface, which enable it to attach itself to some insect or other animal which will transport it to some new locality, where it completes its metamorphosis: about 47 species, 27 species being American; they are not parasitic, but live on dried or decaying animal and plant substances, but are often a pest to housekeepers, gardeners, and grocers, especially as the hypopus is often spread by house flies.

* See "A Revision of the Tyroglyphidae of the United States," by N. Banks, Tech. Ser. No. 13, Bur. of Ent., Dept. of Ag., Washington, 1906.

1. **Tyroglyphus** Latreille. Body elliptical, with a suture between the second and third pairs of legs; male with 2 suckers on each side of the genital pore; mandibles chelate; a sucker at the top of each foot: about 8 species.

Fig. 695
Tyroglyphus farinae (Banks).

T. siro (L.). Cheese mite. Length .6 mm.; width .3 mm.; color whitish: in old cheese and similar substances.

T. farinae (DeGeer) (Fig. 695). Length of male .5 mm.; of female .3 mm.; color whitish: in flour, grain, and stored foods; cosmopolitan; often a pest.

T. linterni Osborn. Similar to the above, but smaller and with very long bristles extending backwards from the body: in mushrooms.

2. **Rhizoglyphus** Claparede. Suture between the second and third pair of legs; mandibles chelate; male with ventral suckers; feet short, with stout claws and spines: 2 species.

R. hyacinthi (Boisduval). Bulb mite. Length .75 mm.: burrows into the bulbs of cultivated plants, giving entrance to fungi and bacteria; often a pest in hot and green houses.

Family 6. ORIBATIDAE.*

Horny or beetle mites. Body minute and divided into 2 parts by a transverse suture; integument hard, with few hairs; a bristle, which is often long, prominent, and club-shaped, and is called the pseudostigmatic organ, arises from a depression near the hinder margin of the cephalothorax on each side (Fig. 696, 1); mouth parts and pedipalps small and hidden beneath the head; mandibles chelate; claws 1 or 3; the young are often very bizarre in shape: about 20 genera with over 300 species, which feed principally on vegetable or decaying animal matter and are not parasitic, but live in moss, grass, among decaying leaves, in crevices of bark, etc.

Key to the genera of *Oribatidae* here described:

a_1 Abdomen with a pair of wing-like expansions.....1. Galumna
a_2 No such expansions.
  b_1 Cephalothorax with a pair of dorso-lateral ridges.
    c_1 Body smooth .....2. Liacarus
    c_2 Body rough; cephalothorax and abdomen not distinctly separated. 3. Scutovertex
  b_2 No such ridges; 3 claws on each leg.
    d_1 Body flat, often rectangular.....4. Nothrus
    d_2 Abdomen very high with concentric rings.....5. Neoliodes

* See "On the Oribatoidea of the United States," by N. Banks, Trans. Am. Ent. Soc., Vol. 22, p. 1, 1895. "Oribatidae," by A. D. Michael, Das Tierreich, 1898. "New Oribatidae from the United States," by N. Banks, Proc. Acad. Nat. Sci., Phila., 1906, p. 490.

1. Galumna Heyden (*Oribata* Michael). Body shining black or brown in color, with a pair of horizontal wing-like expansions at the side of the abdomen and with 3 claws on each foot: 21 American species; in moss or on trees.

G. pratensis Banks. Length .7 mm.; yellowish-brown in color: often common in meadows.

G. emarginata Banks. Body dark reddish-brown in color and .9 mm. long; wing emarginate below: often common in moss, or on the ground.

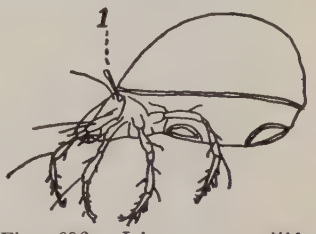

Fig. 696 — *Liacarus nitidus* (Banks); pseudostigmatic organ.

2. Liacarus Michael. Body smooth, last 3 pairs of legs inserted under the body, each ending with 3 claws: 9 American species.

L. nitidus Banks (Fig. 696). Body 1 mm. long, subspherical, shining dark reddish-brown or black: under fallen leaves, stones, etc.; common.

3. Scutovertex Michael. Divisions between cephalothorax and abdomen not very distinct; body rough and sculptured: 2 American species.

S. marinus Banks. Paired bristles on cephalothorax wanting: on the rocks between tide marks on the Atlantic seashore.

Fig. 697—*Neoliodes concentrica* (Banks).

4. Nothrus Koch. Body rough and more or less rectangular; back flat or concave; legs short, thick, and rough, ending with 3 claws: 20 species, which live in moss, on bark of trees, or on rocks, 7 American.

N. excisus Banks. Length .7 mm.; most of the hairs serrated: on the bark of spruce trees; New York state.

N. rugulosus Banks. Body dark brown and very rough, appearing like a piece of dirt: common under loose bark.

5. Neoliodes Berlese. Abdomen convex and very high, with concentric rings; feet with 3 claws: 3 species.

N. concentrica (Say) (Fig. 697). Body black, 1.5 mm. long; color brown: on bark of trees; Europe.

Family 7. GAMASIDAE.

Scavenger mites. Body broad, with short legs; eyes absent; mandibles usually chelate, and beneath them is a bifid hypostome; pedipalps 5-jointed and prominent; legs 6-jointed and ending with 2 claws or with a sucker; tracheae present, a pair of spiracles being located above the

fourth legs, each being surrounded by a chitinous ring called the stigmal plate or peritreme, which usually extends forwards a long distance; the young mostly born with 3 pairs of legs: numerous species and about 18 American genera, some of the species being parasitic on insects, especially beetles, and on vertebrates, while many species use insects for transportation; some lead a free life in moss and on the ground.

Key to the genera of *Gamasidae* here described:

a_1 Free-living or attached to insects and rarely to vertebrates.
b_1 First pair of legs inserted on one side of the mouth opening.
c_1 Leg with one claw; female genital plate triangular.....1. GAMASUS
c_2 Leg 1 without claws; leg 2 thickened.....2. MACROCHELES
b_2 First pair of legs inserted in the same opening as the mouth parts. 4. UROPODA
a_2 Parasitic on birds.....3. DERMANYSSUS

1. GAMASUS Latreille. Body usually flattened, with or without a transverse dorsal suture; female genital plate triangular; male genital pore on anterior margin of sternal plate: about 10 American species, which live on the ground, among fallen leaves, etc., or on insects.

G. coleoptorum (L.). Length .6 mm.; transverse dorsal suture present; 4 large spines projecting from the hinder end; anterior end triangular; first pair of legs with sucking discs: on beetles.

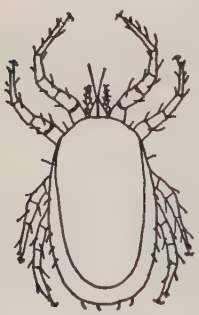

Fig. 698—*Dermanyssus gallinae* (Banks).

2. MACROCHELES Latreille. Body elongate, with no transverse dorsal suture; second leg enlarged, in male curved and armed with teeth; mandibles very thick; male genital pore on anterior margin of sternal plate; first pair of legs without claws: several species.

M. mœstus Banks. Body reddish-brown and 1 mm. long, with 8 rows of clavate hairs above and a few on the hinder margin: common in ants' nests.

3. DERMANYSSUS Dugès. Bird mites. Body elongate and not distinctly constricted; hind legs not reaching the hinder end; mandibles chelate in male, long and piercing in female: parasitic on birds, especially domesticated ones; 1 American species.

D. gallinae (DeGeer). Chicken mite (Fig. 698). Body .7 mm. long, .4 mm. wide, pear-shaped and flat and reddish in color: the mites hide during the day in the coop and at night attack the fowls and suck their blood, and are often a serious pest; they frequently attack dogs, cats, and horses, as well as man.

4. UROPODA Latreille. Body ovoid, with depressions on the under side for the reception of the legs; mandibles very long and slender, and chelate: on beetles, ants, and other insects; some are parasitic, but most

of the species use the insects only for transportation, being young animals in the nymphal stage which attach themselves by a pedicel of excrement: as adults they live on the ground among fallen leaves, and in similar places; several species.

5. U. vegitans (DeGeer) (Fig. 699). Body arched, smooth, brownish in color, about 1 mm. long: common.

Fig. 699—*Uropoda vegitans* (Banks).

Family 8. ARGASIDAE.

Ticks. No scutum, as in the *Ixodidae;* stigmal plate between legs 3 and 4: 16 American species, which are nocturnal parasites of domestic birds.

Argas Latreille. With the characters of the family: about 10 species.

A. persicus Fischer (*A. miniatus* Koch). The Miana bug. Body oval in shape, 5 mm. long in the male and 10 mm. in the female and brown in color: often a dangerous parasite of chickens from Florida to California; cosmopolitan; in western Asia it bites persons and is much feared.

Family 9. IXODIDAE.*

Ticks. Body often large, and covered with a leathery integument capable of great distention in the female, with prominent, slender legs and beak-like mouth parts; anterior dorsal surface covered with a horny shield, the scutum (Fig. 700, B), which in the male extends over the entire back; articulating with the anterior margin of this is the head or capitulum, on which in the female are 2 pitted spots; head bears the short, thick, 3 or 4-jointed pedipalps at the sides and in the middle, the elongated beak or rostrum, which is made up of the 2 mandibular sheaths above, and the toothed hypostome or under lip beneath, with the 2 mandibles between, the latter organs being toothed at the tip; eyes present or not; tracheae present, the spiracles being just behind the last pair of legs, each surrounded by a stigmal plate or peritreme (Fig. 700, C); legs 6-jointed, ending with 2 claws and a pad, the foot of first pair also bearing a sense organ called Haller's organ: parasitic on mammals, birds, and reptiles; the female, when gorged with blood, falls to the ground to lay her eggs; the young ticks, which have but 6 legs at first, usually ascend some plant and are brushed off by a passing vertebrate which can set as a host; 250 species, about 35 American.

* See "The Cattle Ticks of the United States," by D. C. Salmon and C. W. Stiles, Rep. Bureau of An. Ind., U. S. Dept. of Ag., 1902, p. 380. "Ixodidae," by L. G. Neuman, Das Tierreich, 1911.

Key to the genera of *Ixodidae* here described:

a_1 Pedipalps much longer than broad.
b_1 Eyes absent ..... 1. IXODES
b_2 Eyes present ..... 2. AMBLYOMMA
a_2 Pedipalps very short and thick.
b_1 Stigmal plate round ..... 3. MARGAROPUS
b_2 Stigmal plate comma-shaped ..... 4. DERMACENTOR

1. IXODES Latreille. Eyes absent; pedipalps and beak long and of the same length; anal groove surrounds anus anteriorly and is open posteriorly: over 50 species, about 14 in America.

I. ricinus (L.). The castor bean tick. Body oval, in male 3.5 mm. long and 2 mm. broad and high; in female 4 mm. to 11 mm. long, according to the amount of blood it has sucked, and brown or yellow in color; at the base of the first pair of legs in the female is a strong median spine: cosmopolitan; often common on domestic animals, rabbits, etc., also on man.

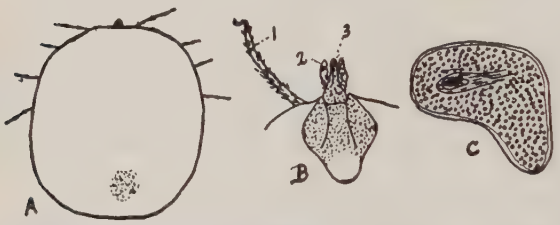

Fig. 700—*Amblyomma americanum* (Hooker). A, dorsal aspect of female; B, the scutum; C, stigmal plate. 1, first leg; 2, pedipalps; 3, rostrum.

I. scapularis Say. Body 3 to 6 mm. long and 2 mm. broad, with a dark brown shield: common in the southern states on all kinds of wild animals, dogs, and cattle.

2. AMBLYOMMA Koch. Eyes present; anal groove surrounds anus posteriorly and is open anteriorly; pedipalps and beak long: 86 species, 4 American.

A. americanum (L.). Lone star tick (Fig. 700). Body 4 mm. long, 3 mm. wide; the gravid female may measure 12 mm. in length and 8 mm. breadth; color of male brown, of female bluish, with a brown scutum, the hinder end of which has a conspicuous yellowish spot, which gives the animal its popular name: often common on cattle, also on man.

3. MARGAROPUS Karsch (*Boophilus* Curtice). Eyes present, often indistinct; pedipalps short and broad, with the second and third joints extended laterally into sharp points; spiracles round: 2 species, 1 American.

M. annulatus* (Say) (*M. bovis* Riley). Texas cattle tick (Fig. 701). Body oval and 2.30 mm. long, and brown in color in male, and elliptical

* See "Texas Fever," etc., by J. R. Mohler. Bull. 78, Bur. Animal Industry, Dept. Ag. 1905.

or more or less rectangular and up to 13 mm. long and yellowish or slate-color in the female: southern states, on cattle, often very common, causing the destructive Texas fever, the disease being caused by the inoculation of the cattle by the tick of *Babesia bigemina,* a sporozoan blood parasite (see page 47).

4. Dermacentor Koch. Eyes present; pedipalps short and broad; stigmal plate comma-shaped; scutum partially white or yellow: 20 species, about 4 American.

D. variabilis (Say) (*D. electus* Koch). Dog tick (Fig. 702). Body oval or rectangular; scutum reddish-brown with white spots; stigmal

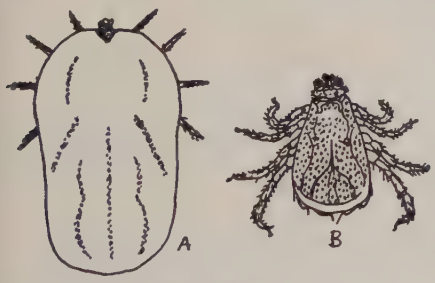

Fig. 701

Fig. 702

Fig. 701—*Margaropus annulatus* (Banks). A, female; B, male. Fig. 702—*Dermacentor variabilis*—male (Banks).

plate finely punctate; color brown, variegated; length of replete female 15 mm.; breadth 9 mm.: on domestic animals and man, often abundant in the eastern and central states, being the tick that often attaches to persons in the woods.

D. venustus* Banks. The Rocky Mountain spotted-fever tick. Body an elongated oval and 2 to 6 mm. long in the male and about 15 mm. long in the female and reddish-brown in color: the northwestern states; the larvae live on small mammals and the adults on the larger domestic animals and man; the cause of a very dangerous fever which is the result of the inoculation by the tick of a sporozoan blood parasite, *Babesia hominis* (see page 47).

Family 10. HYDRACHNIDAE.†

Fresh-water mites. Body usually ovoid or spherical and sometimes of large size, and often brightly colored; 1 or 2 pairs of eyes present;

* See "A Zoological Investigation into the Cause, Transmission, and Source of Rocky Mountain Spotted Fever," by C. W. Stiles, Bull. No. 20, Hyg. Lab., Treasury Department, Washington, 1905.

† See "Nordamerikanische Hydrachniden," by F. Koenike, Abh. d. natur. Ver. zu Bremen, Vol. 13, p. 167, 1895. "Deutschlands Hydrachniden," by R. Piersig, Bibl. Zool. No. 22, 1897 to 1900 "Hydrachnidae und Halacaridae," by R. Piersig und

mandibles with a terminal claw; pedipalps 5-jointed and usually long, the terminal claw being sometimes bent down to form a grasping organ; legs usually 5-jointed, with or without swimming hairs, and joined to body by prominent coxal plates (Fig. 705, 1); a pair of spiracles on the dorsal side of the rostrum; genital pore surrounded by a plate and usually near the center of the body; numerous minute suckers often on each side of the genital pore; eggs laid on plants, stones, etc.; young born with 6 legs and usually go through a complex metamorphosis, often attaching themselves to aquatic insects: about 70 genera and 500 species, most of which live in fresh water, a few being found in brackish water or in the sea, and the genus *Unionicola* being parasitic in mollusks; about 100 American species; 5 subfamilies.

Key to the subfamilies of *Hydrachnidae:*

a_1 Large red mites with 4 eyes close together on a plate.
  b_1 Eye plate long and narrow.....1. LIMNOCHARINAE
  b_2 Eye plate short, broad and paired.....2. EYLAINAE
a_2 Eyes not close together on a plate, but far apart.
  b_1 Pedipalps chelate.
    c_1 Mandibles 1-jointed, straight and needle-like.....3. HYDRACHNINAE
    c_2 Mandibles 2-jointed, the terminal joint a curved hook.4. HYDRYPHANTINAE
  b_2 Pedipalps not chelate.....5. HYGROBATINAE

SUBFAMILY 1. LIMNOCHARINAE.

Body very soft, variable in form, red in color; eyes 4, near together on a long lanceolate plate: 2 genera.

LIMNOCHARES Latreille. Body rectangular; legs without swimming hairs, but with spines, and in 2 widely separated groups of 2 each: the animals do not swim but walk slowly over the mud and plants in the water; 2 species.

L. aquatica (L.) (Fig. 703). Body red, 4 mm. long: on the bottom of ponds; cosmopolitan and common; larvae attached to water skaters (*Hydrometridae*).

SUBFAMILY 2. EYLAINAE.

Body soft, regular in outline, red in color; eyes 4, near together on a paired plate: 2 genera.

EYLAIS Latreille. Body oval, legs long, with swimming hairs, rather close together; genital pore between the first 2 pairs: 35 species, the larvae of which have been found on mosquitoes; 3 American species, which are rapid swimmers.

H. Lohmann, Das Tierreich, 1901. "A Review of the Genera of the Water Mites," by R. H. Wolcott, Trans. Am. Mic. Soc., Vol. 26, p. 161, 1905. "Die Süsswasserfauna Deutschlands, Heft 12, Araneae und Acarina," by F. Koenike, 1909.

E. extendens (O. F. Müller) (Fig. 704). Body red, 4 mm. long: in ponds; cosmopolitan and common.

Subfamily 3. HYDRACHNINAE.

Body soft, sometimes with chitinous plates; 4 eyes, 2 on each side and sometimes another in the middle; rostrum usually elongate, forming a snout, at the end of which is the mouth; mandibles 1-jointed, long and needle-like; pedipalps chelate: 2 genera.

Hydrachna O. F. Müller. Body oval or round; legs rather short, the last 3 pairs with swimming hairs; genital pore between the last 2

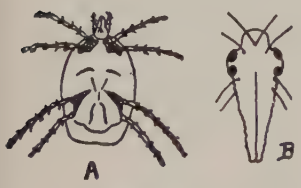

Fig. 703

Fig. 704

Fig. 705

Fig. 703—*Limnochares aquatica* (Banks). A, ventral aspect; B, dorsal eye plate. Fig. 704—*Eylais extendens* (Wolcott). A, ventral aspect; B, dorsal eye plate. Fig. 705—*Hydrachna geographica* (Wolcott). 1, coxal plates; 2, genital plate.

pairs of legs; the larvae attach themselves to aquatic insects: about 33 species, 8 American.

H. geographica (Müll.) (Fig. 705). Body oval, arched, dark red in color with dark spots on the back; length 7 mm.: often common; cosmopolitan.

Subfamily 4. HYDRYPHANTINAE.

Body soft, sometimes with chitinous plates, and red or brownish in color; 1 or 2 eyes on each side and sometimes a median eye; coxal plates in 4 groups: the larva leaves the water and is parasitic on aerial insects, returning to the water to complete its transformation; 13 genera.

Key to the genera of *Hydryphantinae* here described:

a_1 One eye on each side contained in a chitinous capsule, and a median eye.
  b_1 Swimming hairs on legs.....1. Hydryphantes
  b_2 No swimming hairs.....2. Thyas
a_2 Two eyes on each side and no median eye.....3. Diplodontus

1. Hydryphantes Koch. Swimming hairs on the last 3 pairs of legs; median eye surrounded by a chitinous plate, but no other chitinous plates on the dorsal surface: 17 species.

H. ruber (DeGeer) (Fig. 706). Body 2 mm. long, red in color, often tending to be dark: in wood ponds, especially in the springtime.

2. **Thyas** Koch. Like the above but with no swimming hairs on the legs; body flattened: 7 species, 2 American, the larvae of which leave the water and attach themselves to aerial insects.

T. stolli Koenike. Body 1.2 mm. long, oval and red in color; legs with numerous bristles.

Fig. 706

Fig. 707

Fig. 706—*Hydryphantes ruber* (Wolcott). 1, coxal plates; 2, genital plate. Fig. 707—*Diplodontus despiciens* (Wolcott). A, ventral aspect of male; B, pedipalp of female.

3. **Diplodontus** Dugès. Body oval or round; eyes 2 on a side; no median eye; legs with swimming hairs; genital plate heart-shaped: 3 species.

D. despiciens (O. F. Müller) (Fig. 707). Body 2 mm. long, red in color with an indistinct darker dorsal spot, and also covered with papillae; larva on aerial insects: common.

Subfamily 5. HYGROBATINAE.

Body compact, surface smooth or with fine parallel lines, sometimes with chitinous plates; eyes of the 2 sides distant from each other, either 1 or 2 eyes being on a side and never in a capsule; no median eye; pedipalp not chelate, or rarely so; coxal plates large, sometimes covering the whole ventral surface; the larva (except in *Unionicola*) attached to water insects: 53 genera, 2 genera with about 4 species being found in the sea off the coast of France.

Key to the genera of *Hygrobatinae* here described:

a_1 Pedipalps not chelate.
  b_1 Coxal plates not fused together.
    c_1 Coxal plates in 3 groups.....1. Hygrobates
    c_2 Coxal plates in 4 groups.
      d_1 Fourth leg ending with a claw and not a bristle.
        e_1 Free-swimming; fourth joint of pedipalp with 2 papillae.....2. Piona
        e_2 Parasitic in mussels.....3. Unionicola
      d_2 Fourth leg ending with a long bristle.....4. Limnesia
  b_2 Coxal plates fused into a single plate.....5. Koenikea
a_2 Pedipalps chelate; body of male with a posterior appendix...6. Arrhenurus

1. **Hygrobates** Koch. Body ovoid; coxal plates of female in 3 groups; no swimming hairs present; genital pore midway between the hinder coxal plates and the hinder end of the body with 3 or more suckers on each side: 11 species, 4 American.

H. longipalpis (Hermann) (Fig. 708). Body 2.5 mm. long and yellow in color, very convex dorsally; pedipalps almost half as long as the body: cosmopolitan.

2. Piona* Koch (*Curvipes* Koenike). Fourth joint of pedipalp usually with 2 papillae; legs all with swimming hairs; genital pore close behind the hind coxal plates: 19 American species, among the largest and most active hydrachnids.

P. spinulosa (Wolcott) (Fig. 709). Body broadly elliptical and about .5 mm. long, being one of the smallest of the genus and nearly transparent, with patches of dark brown and a spot between the large eyes; coxal plates close together and covering most of the ventral surface; legs long and with few spines; 20 to 30 suckers on each side of genital pore: widely distributed and common in central states.

Fig. 708—*Hygrobates longipalpis* (Wolcott).

3. Unionicola† Haldeman (*Atax* Fabricius). Body ovoid or round; genital opening at the hinder end of body, the plate on each side of the opening bearing many minute suckers; pedipalps long, in the parasitic forms thick; first pair of legs usually thick, in the nonparasitic species with long, movable spines; third and fourth pair of legs with swimming hairs: 16 American species, most of which are parasitic either in youth or permanently, on the gills of *Unionidae* and occasionally other mollusks.

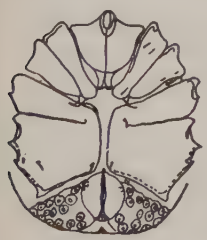

Fig. 709
Piona spinulosa
(Wolcott).

U. ypsilophora (Bonz). Body ovoid, about 1.3 mm. long, yellowish-white in color with large brown or black spots, and a yellow Y-shaped mark on the back; about 20 minute suckers on each side of genital pore; first pair of legs not thicker than the others: widely distributed and common in the eastern and central states, occurring, with rare exceptions, in species of *Anodonta;* Europe.

U. fossulata (Koenike). Body ovoid, about 1.4 mm. long; 5 suckers on each side of genital pore; first pair of legs not so thick as the pedipalps: central states, common, occurring, with rare exceptions, in species of *Unio.*

4. Limnesia‡ Koch. Body ovoid; fourth pair of legs without the terminal claws, but with a bristle at the tip; pedipalps long with the second joints thickened; 3 or 4 suckers on each side of the genital pore; 4 eyes: 6 American species.

* See "The North American Species of Curvipes," by R. H. Wolcott, Trans. Am. Mic. Soc., Vol. 23, p. 201, 1902.

† See "On the North American Species of the Genus Atax Fabr.," by R. H. Wolcott, Trans. Am. Mic. Soc., Vol. 20, p. 193, 1899.

‡ See "On the North American Species of Limnesia," by R. H. Wolcott, Trans. Am. Mic. Soc., Vol. 24, p. 85, 1903.

L. histrionica (Hermann) (Fig. 710). Length of female 2 mm.; breadth 1.7 mm.; male half as large; color variable but usually yellowish with dark patches and red spots on the back; legs bright green; eyes red; body marked with faint wavy lines; pedipalps very long and thick: very common over the whole country; Europe.

5. **Koenikea*** Wolcott. Body round, flat or concave on dorsal surface, with a long curved rostrum in the female; coxal plates of male fused into a single plate, and in the female into 2 plates; legs with

Fig. 710

Fig. 711

Fig. 710—*Limnesia histrionica* (Wolcott). Fig. 711—*Arrhenurus americanus* (Marshall). A, ventral aspect of male; B, ventral aspect of female.

swimming hairs; numerous minute suckers on each side of the genital pore: 1 species.

K. concava Wolcott. Body .67 mm. long; eyes 2, widely separated: common and widely distributed over the eastern and central states.

6. **Arrhenurus**† Dugès. Integument very hard and porous; back with a circular furrow enclosing the dorsal shield; female oval in shape; male with the hinder end very much prolonged, forming an appendix; eyes widely separated; coxal plates of the first 2 pairs of legs contiguous; also those of the last 2 pairs; pedipalps chelate: 150 species, 50 American.

A. marshalli Piersig. Body of male 1 mm. long with the appendix very long, cylindrical and constricted at the base; female .8 mm. long and oval; color blue-green, occasionally orange: cosmopolitan and common, usually the most abundant of the genus.

A. americanus Ruth Marshall (Fig. 711). Male .92 mm. long; appendix widest at hinder end; color greenish, tinged with red; female 1.12 mm. long and ovate in form: abundant in the Middle West.

* See "New Genera and Species of North American Hydrachnidae," by R. H. Wolcott, Trans. Am. Mic. Soc., Vol. 21, p. 189, 1900.

† See "The Arrhenuri of the United States," by Ruth Marshall, Trans. Am. Mic. Soc., Vol. 22, p. 85, 1908.

Family 11. HALACARIDAE.*

Salt-water mites. Body rather elongate, usually with a suture between the 2 pairs of legs; rostrum often large; 3 eyes usually present; no tracheae; no swimming hairs on legs: about 10 genera and 70 species known; the animals are found crawling slowly over algae in the sea, being vegetal feeders; the young feed on the eggs of copepods and are attached to various animals; 1 fresh-water species.

Halacarus Gosse (*Thalassarachna* Packard). Pedipalps 4-jointed, long, free, and distant from each other; body convex and rather elongate; first leg but little thicker than the second: about 41 species, 1 in fresh water.

H. verrilli (Packard). Body ovoid with a transverse suture, just back of which is a pair of black eyes; color dark, rostrum conical; mandibles slender and almost as long as the pedipalps; length 1.75 mm.: on hydroids off the coast of Maine.

Family 12. BDELLIDAE.

Snout mites (Fig. 712). Body elongate, with a transverse suture between the second and third pairs of legs; mandibles very long and large; pedipalps long and slender; spiracles at the base of the rostrum: about 13 American species, which are active predacious animals living in moss, rotten wood, and similar places, and can move backwards as well as forwards.

Fig. 712
A snout mite (Banks).

Bdella Latreille. Palps used like antennae and elbowed, the last joint bearing 2 or more long bristles; mandibles chelate: about 10 American species.

B. marina Packard. Body red in color and 2 mm. long; last joint of pedipalp not widened at tip, hairs at end not as long as the joint; many bristles on body: along Atlantic seaboard.

B. cardinalis Banks. Body red in color and 1.2 mm. long; last joint of pedipalp widened at tip, and with hair at end much longer than joint; body with about 20 bristles: in moss and on the ground.

Family 13. TROMBIDIIDAE.

Harvest mites. Body globular or elongate, red in color, and hairy, usually with a transverse suture between the second and third legs; mandibles chelate; eyes often stalked (Fig. 713); legs end with 2 claws; pedipalps 5-jointed; spiracles at the base of the mandibles; the larvae

* See "Hydrachnidae und Halacaridae," by R. Piersig and H. Lohmann, Das Tierreich, 1901.

have 3 pairs of legs and are parasitic on insects, spiders, etc., *Trombidium* being very common on house flies in the autumn, certain species, especially in the southern states, attacking man: about 4 American genera with 30 species, none of which are parasitic as adults.

Trombidium Fabricius. Mandibles chelate; eyes stalked: about 12 American species, which are found on plants and on the ground, and walk slowly.

T. sericeum Say. Body broadest in front, densely covered with short silken hair; eyes 2 and stalked and white: the commonest species in the eastern states, living on trees and on the ground.

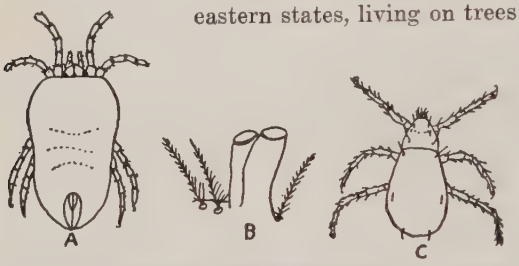

Fig. 713—*Trombidium locustarum* (Banks). A, ventral aspect of male; B, eye-stalks; C, a larva.

T. locustarum Riley (Fig. 713). Body elongate, red, tapering behind; male with a sunken elliptical area above; 4 to 5 mm. long: on ground, young on grasshoppers.

Family 14. RHYNCHOLOPHIDAE.

Like the *Trombidiidae*, but with piercing mandibles and sessile eyes; a mid-dorsal line or furrow on cephalothorax: 3 American genera, the individuals of which walk rapidly.

Rhyncholophus Dugès. Mandibles slender, needle-like, and retractile; eyes 4 and sessile; legs long: 15 American species, which feed on small insects, such as aphids and scales, and run rapidly.

R. simplex Banks. Body red, 2.2 mm. long, with some erect bristles on the body and among them many fine hairs; all legs long, hind pair longer than the body: on dry ground.

R. maculatus Banks (Fig. 714). Body with red spine-like hairs, leaving several smooth white patches; legs short, hind pair no longer than body; length 1.5 mm.: on ground and plants.

Family 15. TETRANYCHIDAE.*

Red spiders. Body oval, with a few bristles arranged in about 4 rows, and with a transverse suture between the second and third pairs of legs, and red in color; 2 or 4 eyes, without stalks; pedipalps 4-jointed, the penultimate joint usually with a strong claw; mandibles with their basal portions fused and tips long and flexible, and fitted for piercing

* See "The Red Spiders of the United States," by N. Banks, Bull. No. 8, Tech. Ser., Div. Ent., U. S. Dept. Agr., 1900.

the plant tissues, on the juices of which the animal usually lives: on plants and the ground, often a pest in greenhouses; about 6 American genera, with 20 species.

1. **Tetranychus** Dufour. Pedipalps short, ending with a thumb-like projection; the animals are able to spin a web, by means of which they fasten the minute red eggs to leaves; first pair of legs longer than the body: about 14 American species.

Fig. 714

Fig. 715

Fig. 716

Fig. 714—*Rhyncholophus maculatus* (Banks). Fig. 715—*Tetranychus bimaculatus* (Banks). Fig. 716—*Bryobia pratensis* (Banks).

T. bimaculatus* Harvey (*T. cucumeris* Boisduval) (Fig. 715). But 1 claw on each foot, which splits into 4 near the tip; color and size variable; color usually red, but sometimes yellowish with black dots: often common on vegetables and cultivated flowers, both in greenhouses and out of doors.

2. **Bryobia** Koch. Body with scale-like hairs above: 1 American species.

B. pratensis Garman (Fig. 716). The clover mite. Body red with 4 scale-like hairs projecting in front; first pair of legs longer than the others: often numerous on clover and fruit trees; eggs red, on fruit trees in winter; they often hibernate in houses, and may become a nuisance.

Order 9. LINGUATULIDA.†

Worm-like arachnids (Fig. 717, A), in which the abdomen is very much elongated and composed of a large number of short rings, which

* See "The Common Red Spider (*Tetranychus bimaculatus*)," etc., by F. H. Chittenden, Cir. 29, Div. of Ent., U. S. Dept. of Agr., 1909.

† See "Contribution to Helminthology," by J. Leidy, Proc. Acad. Nat. Sci., Phila., Vol. 5, p. 96. "A Synopsis of Entozoa," etc., by the same, same, 1856, p. 42. "Description of Pentastomum prob.," by the same, same, 1884, p. 140. "Bau u. Entwick. von Pentastomum," etc., by C. W. Stiles, Zeit. f. Wiss. Zool., Bd. 52, 1891. "An Attempt to Revise the Family Linguatulidae," by A. E. Shipley, Arch. de Parasit., Vol. 1, p. 52, 1898.

are not, however, equivalent to somites. The cephalothorax is very short and bears on its ventral side 2 pairs of hook-like retractile claws. Excretory, respiratory, circulatory, and sense organs are all absent. The digestive tract is a straight tube. The nervous system consists of a subœsophageal ganglion and a circumœsophageal ring. The sexes are separate, the male genital pore being near the mouth, the female near the anus at the hinder end. The linguatulids live as parasites in the air passages and also in the body cavity of certain mammals and reptiles. The eggs reach the outside world together with the discharges of the host and must be swallowed by a mouse, rabbit, or other small animal in order to develop. The larva (Fig. 717, B), hatching in the stomach of this intermediate host, is quite mite-like in appearance and has 2 pairs of legs and boring mouth parts. It makes its way into the liver, peritoneum, or other organ, where it encapsules itself and here undergoes the greater part of its metamorphosis and attains the form of the adult, except that it has a circle of spines around each ring and is not sexually mature. It may then leave its cyst and migrate through the tissues of the host, and may reenycst in some other locality. If the intermediate host is then eaten by the final host, the parasite passes into its final resting place in the latter. It may, for instance, pass directly from the mouth into the nasal passages, or it may migrate from the stomach or intestine through the intestinal wall into the lungs, or air passages, where it becomes mature.

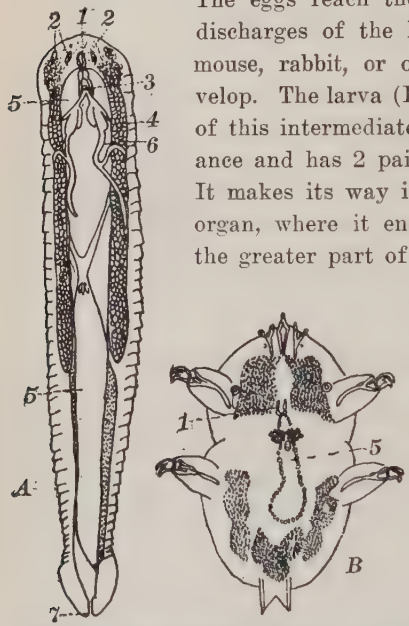

Fig. 717.—*Porocephalus crotali.* A, diagram showing anatomy; B, a larva (Stiles). 1, mouth; 2, hooks; 3, genital pore; 4, testis; 5, intestine; 6, sperm duct; 7, anus.

The linguatulids were formally classed among the worms, but the resemblance of the body of the adult to that of eriophyid mites and of the larva to the short-bodied mites, as well as their voluminous body cavity and striated muscle fibres, have caused them to be placed among the *Arachnida*. Both the adult and larva are occasionally found in man. The order contains 3 genera and about 26 species.

Key to the genera of *Linguatulida* here described:

a_1 Body flat.....1. LINGUATULA
a_2 Body cylindrical.....2. POROCEPHALUS

1. Linguatula Frölich (*Pentastomum* Rudolphi). Body flat, with a convex back and scalloped edges; cephalothorax usually not so broad as the abdomen: 4 species.

L. tænioides (Lamarck). Body lanceolate; number of abdominal rings about 90; length of female 85 mm.; width 10 mm.; length of male 20 mm.; width 3 mm.: the adult occurs in the frontal sinus of the dog and horse and in the nasal cavities of the dog, horse, wolf, fox, goat, and man; the larvae form (*P. denticulatum*) is 5 mm. long and 1.5 mm. wide and occurs in the liver, lungs, and other organs of the cat, horse, rabbit, rat, and other animals.

2. Porocephalus Humboldt (*Pentastomum* Rudolphi). Body cylindrical; head usually, but not always, as wide as the abdomen: 21 species.

P. crotali Humb. (*P. proboscideum* Rud.) (Fig. 717). Body subclavate; number of rings about 40; length of female 80 mm.; width 7 mm.; length of male 56 mm.; width 5 mm.: the adult occurs in the lungs and body cavity of the rattlesnake and boa constrictor and a few other animals; the larva (*P. subcylindricus*) occurs in the liver and body cavity of the mouse and other small animals.

Order 10. TARDIGRADA.*

Water bears. Minute, usually aquatic animals with a cylindrical unsegmented body, tapering slightly at both ends and with 4 pairs of short legs, each ending with several claws, the last pair of legs being at the hinder end of the body. No mouth parts are present, but a pair of retractile teeth project from the mouth, beside which are the openings of a pair of large salivary glands. Respiratory, excretory, and circulatory organs are wanting. The digestive tract is a straight tube. The nervous system consists of a brain and 4 pairs of ventral ganglia; a pair of eyes are usually present. The animals are hermaphroditic, the single gonad opening into the cloaca; the eggs are usually laid while the female is moulting and the young develop in the empty skin.

The tardigrads are microscopic animals which are found among aquatic vegetation and at the bottom of standing water, and also in moss and other damp places, where they live on both vegetal and animal food. They possess the ability to exist in a desiccated condition for several years. The systematic position of these animals is very obscure. They are usually placed near the mites among arachnids, because of their 4 pairs of legs and small unsegmented body, but their simple structure, primitive legs, lack of mouth parts, and unstriated muscle fibres seem to

* See "Beiträge zur Naturgeschichte der Tardigarden," by L. H. Plate, Zool. Jahrb., Abt. für. Anat., Bd. 3, 1888.

indicate that they are the most primitive of all arthropods. The order contains about 6 genera and 50 species.

1. **Macrobiotus** S. Schultze. Claws all or in part double and often of different lengths; dark but never red pigment in the integument; no feelers or cirri on head; a pair of strong teeth in the mouth: 7 species.

Fig. 718
Macrobiotus hufelandi (Lang).

M. hufelandi Schul. (Fig. 718). Each leg ends with 2 double claws, the 2 sides of each pair being firmly fused and one of them with a small branch claw; length .7 mm.: common in fresh-water ponds.

2. **Echiniscus** S. Schultze. Claws all single and not double, several being on a leg, all of the same length; 2 red eyes present, also short cirri or feelers beside the mouth on each side; 2 long teeth in the mouth; the cuticula, jointed on the back, often has red spots in it, and usually spines or hairs project from it: about 13 species in both fresh and salt water.

E. sigismundi Schul. Third leg with a short spur; each leg ends with about 8 claws; 2 sharp palps on each side beside the mouth, and 2 more beside the eye; length .2 mm.: marine, among algae.

E. testudo Doyère. Body reddish in color and opaque; length .3 mm.: often in the moss of damp roofs.

Order 11. **PYCNOGONIDA.*** (Pantopoda.)

Sea spiders. Marine arachnids, usually of small size, in which the body consists of a large segmented cephalothorax and a minute rudimentary abdomen (Fig. 719). Seven pairs of appendages are present, of which the hinder four pairs are the very long, 9-jointed legs, which seem to have developed at the expense of the trunk, as it is reduced to the smallest proportions. The three forward pairs of appendages are the long chelate mandibles, the slender pedipalps, and the slender ovigerous legs, which are wanting in the females of certain species. The cephalothorax is made up of the following five segments: the anterior more or less cylindrical rostrum, at the front end of which is the mouth; a large segment bearing the mandibles, the pedipalps, the ovigerous legs and the first pair of walking legs, as well as 4 eyes; and 3 segments, each bearing a pair of legs. The digestive tract is complex in structure, long diver-

* See "The Pycnogonida of New England and Adjacent Waters," by E. B. Wilson, Rep. U. S. Fish. Com. for 1878, p. 463, 1880. "A Contribution to the Embryology and Phylogeny of the Pycnogonids," by T. H. Morgan, Studies Biol. Lab., Johns Hop. Univ., Vol. 5, 1890. "Notes on the Habits of Pycnogonids," by L. J. Cole, Biol. Bull., Vol. 2, p. 195, 1901. "Pycnogonida," by D. W. Thompson, Camb. Nat. Hist., Vol. 4, p. 500, 1909.

ticula extending off from the intestine into the legs and the mandibles almost to their tips. The anus at the end of the abdomen. No respiratory or excretory organs are present. The nervous system consists of a brain and a ventral nerve chord with five pairs of ganglia. The sexes are separate, the gonads consisting of a pair of testes or ovaries which are fused together in the adult and much branched. The genital pores are situated in most cases on the second segment of the last two legs in the male and of all the legs in the female. The eggs are carried by the males on the ovigerous legs and hatch usually into six-legged larvae, which go through a metamorphosis. The larva of *Pallene* resembles the adult at hatching.

The pycnogonids live among marine algae and on hydroids, and vary in length from a millimeter to a number of centimeters. Their systematic position is very obscure, but they are usually grouped with the arachnids. They differ from these animals, however, in having seven pairs of appendages, a difficulty which may be overcome by considering the last pair of legs abdominal and homologizing them with the first pair of embryonic abdominal legs, which characterize the other arachnids. The animals have been classed with the *Crustacea* and the larva compared with the nauplius, to which it has a superficial resemblance. They have also been derived from a primitive annelid ancestor and the characteristic larva compared with a modified annelid larva. The order contains about 9 families and over 200 species.

Key to the families of *Pycnogonida* here described:

a_1 Mandibles wanting.....1. PYCNOGONIDAE
a_2 Mandibles present.
b_1 Mandibles not chelate.....2. AMMOTHEIDAE
b_2 Mandibles chelate.
c_1 Pedipalps wanting.....3. PALLENIDAE
c_2 Pedipalps present.....4. NYMPHONIDAE

FAMILY 1. PYCNOGONIDAE.

Body broad and flat; mandibles and pedipalps wanting: 1 genus.

PYCNOGONUM Brünnich. Ovigerous legs 10-jointed, wanting in the female; accessory claws wanting: 10 species.

P. littorale (Ström) (Fig. 719). Length 16 mm.; spread of legs 38 mm.; eyes small, black, and widely separated, on a prominent tubercle; ovigerous legs very small: Long Island Sound to Gulf of St. Lawrence, from low-water mark to 400 fathoms, usually under stones; cosmopolitan; Europe.

FAMILY 2. AMMOTHEIDAE.

Body broad and thick; mandibles not chelate; accessory claws present or not: 9 genera and 30 species.

Tanystylum Miers. Mandibles 1-jointed and rudimentary; pedipalps 6-jointed; ovigerous legs 10-jointed and present in both sexes; accessory claws present: 8 species.

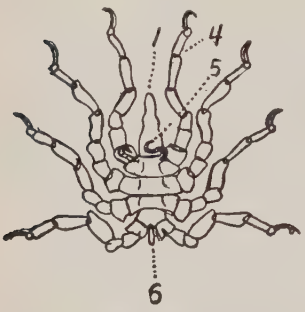

Fig. 719

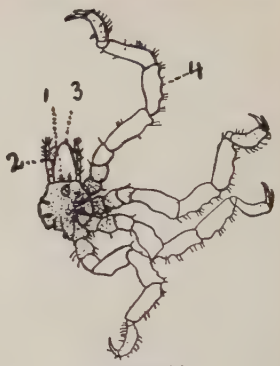

Fig. 720

Fig. 719—*Pycnogonum littorale* (Wilson). Explanations as in Fig. 721. Fig. 720—Tanystylum obiculare (Wilson). Explanations as in Fig. 721.

T. obiculare E. B. Wilson (Fig. 720). Length 1.5 mm.; spread of legs 6.4 mm.; ovigerous legs about half as large in the female as in the male: Vineyard Sound from low-water mark to 14 fathoms, on hydroids or ascidians growing on wharves, etc.

Family 3. PALLENIDAE.

Body rather stout; mandibles chelate; pedipalps wanting; accessory claws wanting or not: 8 genera and 60 species.

1. Pallene Johnston. Mandibles 3-jointed; legs very long; ovigerous legs 9-jointed; accessory claws present: 10 species.

P. empusa E. B. Wilson. Length 1.5 mm.; spread of legs 13 mm.; eyes red; ovigerous legs about a third as long as the other legs in the male, and smaller in the female: Long Island and Vineyard Sounds, on hydroids in shallow water.

2. Anoplodactylus E. B. Wilson. Body slender; rostrum rounded; mandibles 3-jointed; ovigerous legs 6-jointed and wanting in female; accessory claws absent: 12 species.

A. lentus Wils. Length 7 mm.; spread of legs 30 mm.; eyes brown or black; rostrum and mandibles long; ovigerous legs stout; legs very long; color purple, sometimes gray or brown: common between tide marks and in shallow water in Vineyard Sound, on hydroids and ascidians.

Family 4. NYMPHONIDAE.

Body slender or broad, with a large tapering rostrum; mandibles chelate; pedipalps present: 4 genera; 55 species.

Nymphon Fabricius. Body slender, mandibles 3-jointed; pedipalps 5-jointed; ovigerous legs present in both sexes and 11-jointed; legs slender, with accessory claws: 45 species.

N. strömi Kröyer (Fig. 721). Length 15 mm.; spread of legs 14 cm.; ovigerous legs 19 mm. long, stout, slightly hairy: on muddy bottoms.

N. longitarse Kröyer. Length 7 mm.; spread of legs 65 mm.; entire animal extremely slender, ovigerous legs especially so: common from Cape Cod to Nova Scotia, in from 16 to 115 fathoms.

N. grossipes (Fabricius). Length 10.5 mm.; spread of legs 9 cm.; color light yellow, often with purple-banded legs; eyes black, on a prominent tubercle; ovigerous legs very slender: very common from Long Island Sound to Nova Scotia, in from 12 to 110 fathoms.

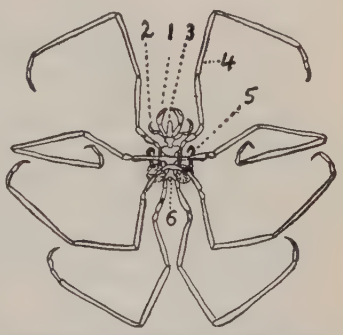

Fig. 721—*Nymphon strömi* (Wilson). 1, mandible; 2, pedipalps; 3, rostrum; 4, first leg; 5, ovigerous leg; 6, abdomen.

Class 3. TRACHEATA.

Air-breathing arthropods with a distinct head and a single pair of antennae, which respire through tracheae.

External Characters.—The more primitive tracheates are worm-like animals in which the body is made up of a large number of similar segments, without any division into thorax and abdomen; the head, however, is always distinctly set off. In the insects, the highest members of the group, the body is divided into the three regions, head, thorax, and abdomen. The paired appendages in the primitive tracheates occur along the entire length of the body, a pair extending from each somite, except usually the last one. In the insects, however, as in the *Arachnoidea,* the abdomen is usually not provided with locomotory appendages. The head appendages are a pair of antennae, which are preoral in position, a pair of mandibles, which have no palps, and in most cases two pairs of maxillae. A diagram showing the homologies of the appendages of tracheates and the other arthropods is given on page 323.

The *Tracheata* are preeminently terrestrial and aerial animals and breathe atmospheric air by means of tracheae, which open to the outside through pores called spiracles. A very few insects live on the surface of the sea and a considerable number of species are found in fresh water; in the case of the latter, certain insect larvae breathe water, but most aquatic tracheates still breathe the atmospheric air. The class contains 3 divisions.

Key to the divisions of *Tracheata:*

a_1 Body worm-like, with a large number of pairs of legs.
b_1 Body not externally segmented; animals tropical and subtropical.
1. ONYCHOPHORA
b_2 Body distinctly segmented.....2. MYRIAPODA
a_2 Body divided into head, thorax, and abdomen; 3 pairs of legs....3. INSECTA

DIVISION 1. ONYCHOPHORA.* (PROTRACHEATA.)

Primitive, worm-like tracheates which combine annelid with tracheate characters. The surface of the body does not show segmentation, but is annulated, and from its ventral surface projects a series of pairs of short annulated appendages, which in the various species may number from 14 to 43 pairs. The head bears a pair of simple eyes, a pair of segmented antennae, a pair of hooked jaws surrounded by a circular lip, and a pair of short leg-like oral papillae in which are the apertures of a pair of slime glands; the sticky secretion of these glands serves to catch insects and spiders. Coxal glands, of which there are as many pairs as legs, are also present. On the under surface of each leg also is a conspicuous elongated groove which is the opening of a nephridium. The skin is soft and thickly beset with papillae.

The body cavity resembles that of insects in being an extensive blood space and not a true cœlom. The digestive system consists of a straight tube passing from the mouth to the anus at the hinder end of the body; the only digestive glands are a pair of long salivary glands. The heart is a long muscular tube with segmental, paired openings. The respiratory system consists of bunches of short tracheae, each of which opens through a spiracle to the outside, and which are scattered irregularly above and between the legs. The excretory system consists of a pair of nephridia at the base of each pair of legs. Each nephridium opens into a vesicle which is a remnant of the cœlom, and externally in the elongated groove on the under surface of a leg. The nervous system consists of a dorsal brain and of a pair of ventral chords which extend from the brain the length of the body and unite behind the anus; they are joined by numerous transverse commissures. The sexes are separate, the genital opening lying in front of the anus. The gonads are paired, their ducts being modified nephridia. Some species are viviparous and some lay eggs. In many forms the egg contains much yolk and segments superficially, as is the case in insects, while in others it is poor in yolk and segmentation is total, and the embryo is enclosed in folds of the uterus and nourished by means of a placenta.

* See "Monographie des Onychophores," by E. L. Bouvier, Ann. des Sci. Nat., Zool., 1907. "The Present Distribution of the Onychophora," etc., by A. H. Clark, Smithsonian Misc. Coll., Vol. 65, 1915.

The *Onychophora* live under bark and stones and in other damp, dark places and feed on insects and other small animals.

History.—Peripatus was first described in 1825 and classified, because of its slug-like appearance, with the mollusks. It was, however, soon after placed among the worms and in 1851 was made one of the subdivisions of annelids by Grube, to which he gave the name *Onychophora*. Burmeister in 1856 placed the group between the annelids and the arthropods, and Moseley in 1874 finally demonstrated its relationship to the latter group by showing the presence of tracheae.

The division contains 2 families with about 12 genera and 75 species, which are found in the Malay Peninsula, the East Indies, Australia, New Zealand, Africa, South and Central America, and the West Indies.

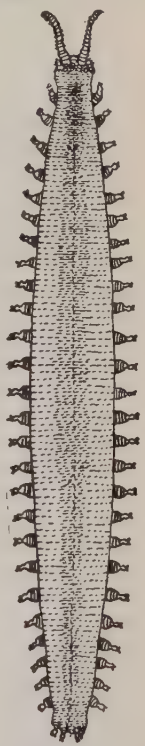

Fig. 722
Peripatus eiseni (Wheeler).

Family PERIPATIDAE.

Sexual orifice between the penultimate pair of legs; 14 annulations to a somite on the back: tropical America; East Indies; tropical Africa; about 5 genera and 50 species.

Peripatus Guilding. Number of pairs of legs from 23 to 43, but is variable in the same species; legs with 4 to 7 spinous pads; feet with 3 to 7 distal papillae; eggs minute; embryo with placenta: about 40 species.

P. (*Oroperipatus* Cockerell) **eiseni*** Wheeler (Fig. 722). Length 40 to 57 mm.; number of pairs of legs 23 to 29; color reddish-brown: from Tepic, Mexico, to Brazil.

Division 2. MYRIAPODA.†

Tracheates with a distinct head and a trunk which is made up of a large number of similar segments, each of which usually bears one or two pairs of jointed appendages. The number of segments may vary from eleven in *Glomeris* and *Polyxenus* to one hundred and seventy-three in certain *Geophilidae*. The legs end each in a single claw, except in the *Symphyla,* in which each leg has two claws. The appendages of the head consist of a pair of segmented antennae, a pair of mandibles, and one or two pairs of maxillae. The mandibles are without palps and

* See "A New Peripatus from Mexico," by W. M. Wheeler, Jour. Morph., Vol. 15, 1899.

† See "The Myriapoda of North America," by H. C. Wood, Jr., Trans. Am. Phil. Soc., Vol. 13, p. 137, 1865. "The Classification of the Myriapoda," by J. S. Kingsley, Am. Nat., Vol. 22, p. 1118, 1888. "The Myriapoda of North America," by C. H. Bollman, Bull. No. 46, U. S. Nat. Mus., 1893. "Myriapoda," by C. Verhoeff, Bronn's Klassen und Ord., etc., 5 Bd., 11 Abt., 1902-1907.

adapted for biting, except in the *Polyzoniidae,* in which the mouth parts are suctorial. The *Chilopoda,* like the insects, have two pairs of maxillae; the other *Myriapoda* have but one pair. In the *Chilopoda,* also, the first pair of legs project forward beneath the head and are transformed into hook-like claws or maxillipeds, each of which has a poison gland. Myriapods possess a pair of eyes, each consisting of a group of ocelli; in *Scutigera,* however, compound eyes are present. The internal organs are similar to those of insects. The sexes are separate, the single genital pore in the *Chilopoda* being in the penultimate segment and the paired pores of the *Diplopoda* in the second body segment. All *Myriapoda* lay eggs. The young are born as larvae with three pairs of legs in the *Pauropoda* and *Diplopoda* and six, seven, or more pairs in the *Symphyla* and *Chilopoda;* in certain of the latter group the larva possesses as many legs as the adult, although they are not all well grown.

All *Myriapoda* are terrestrial animals which live in dark, damp places and avoid the light. The *Chilopoda* live on animal and most of the *Diplopoda* on vegetable food.

History.—Myriapods have been known from time immemorial and usually much feared on account of the dangerous bite of certain of them. Aristotle mentions both centipeds and millipeds, using the still familiar names of *Scolopendra* and *Julus.* Both of these names were adopted by Linnæus for his two genera of the animals, which he placed among the *Insecta aptera.* The name *Myriapoda* was created by Latreille in 1796. The animals were, however, retained among the insects until 1814, when Leach formed a separate class of them equivalent to the *Insecta.* The career of the group since that time has been a checkered one, having been placed by some authors among the *Crustacea* and by others among the *Arachnida* or the *Insecta.* Its right to be considered an independent group may be said to have been definitely fixed by Newport (1844) and Koch (1847). In later years attention has been called to the fact by Kingsley,* Verhoeff, and others that the *Myriapoda* form two groups instead of a single one, one of which, the *Chilopoda* (Latreille 1817), stands in close relationship to the insects, while the other, the *Progoneata* (Pocock 1895), occupies an independent position.

The number of known species of *Myriapoda* is about 1,000, grouped in two orders.

Key to the orders of *Myriapoda:*

a_1 Genital pore near forward end; body usually cylindrical, with mostly 2 pairs of legs to a segment.....1. PROGONEATA

a_2 Genital pore near hinder end; body flattened, with 1 pair of legs to a segment .....2. CHILOPODA

* See "The Classification of the Arthropoda," by J. S. Kingsley, Am. Nat., Vol. 28, pp. 118 and 220, 1894.

Order 1. PROGONEATA.

Body usually cylindrical; usually 2 pairs of legs to a segment; but one pair of maxillae; with anteriorly placed genital pore; tracheae without anastomoses and spiracles which cannot be closed: 3 suborders.

Key to the suborders of *Progoneata:*

a_1 Animals minute; but 1 pair of legs to a segment.
b_1 Antennae not branched.....1. Symphyla
b_2 Antennae with 3 terminal branches.....2. Pauropoda
a_2 Animals not minute; 2 pairs of legs to most segments; millipeds. 3. Diplopoda

Suborder 1. SYMPHYLA.*

Minute, colorless myriapods with a flattened body consisting of a head and 14 segments, with 12 pairs of legs, each of which terminates with 2 claws; projecting from the basal joint of each leg of the 10 hinder pairs is a minute movable branch or parapod; antennae long; eyes absent or minute; mouth parts consist of a pair of mandibles and a pair of maxillae which form a sort of underlip; a pair of long thick cerci project from the hinder end of the body, each of which has a spinning gland; 2 spiracles present at the base of the antennae; the median, genital pore is in the fourth segment; young born with 6 or 7 pairs of legs: 1 family, 2 genera, and about 24 species, of which 4 are American, which are active animals, found under stones, etc., in moist places.

Family SCOLOPENDRELLIDAE.

With the characters of the order: 2 genera.

1. Scutigerella Ryder. Posterior margin of all the dorsal plates except the last either convex or emarginate, with 2 lobes; head sharply

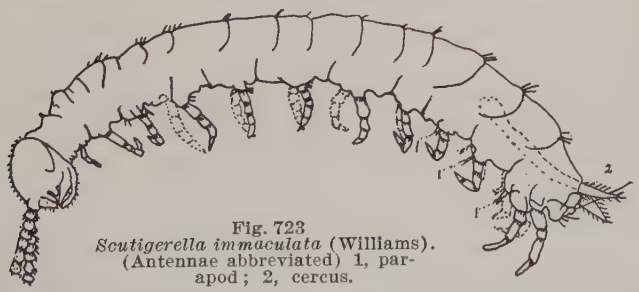

Fig. 723
Scutigerella immaculata (Williams). (Antennae abbreviated) 1, parapod; 2, cercus.

separate from the trunk in the mid-dorsal area; first pair of legs well developed and more than half as long as the following pair: 10 species, 2 in America.

* See "The Structure, Affinities and Species of Scolopendrella," by J. A. Ryder, Proc. Acad. Nat. Sci., Phila., for 1881, p. 79. "Scolopendrella and Its Position in Nature," by A. S. Packard, Jr., Am. Nat., Vol. 15, p. 698, 1881. "The Genera and Species of the Order Symphyla," by H. J. Hansen, Quart. Jour. Mic. Soc., 1903.

S. immaculata * (Newport) (Fig. 723). The last dorsal plate with a very deep, median cavity; second plate deeply emarginate behind; antenna with 19 to 50 joints; length up to 7.5 mm.: Massachusetts to Texas, in old stumps, under moss, etc.; Europe.

S. nivea (Scopoli) (*S. gratiae* Ryder). No deep cavity in the last dorsal plate, each segment with a pair of long setae projecting straight out from body; second plate with the hinder margin straight or nearly so; length 2.5 mm.: eastern United States; Europe.

2. **Scolopendrella** Gervais. Posterior margin of all the dorsal plates except the last in form of a pair of triangular plates; head not sharply separate from the trunk; first pair of legs often rudimentary: 12 species, 2 American.

S. texana Hansen. Length 2.8 mm.; antennae with 19 to 22 joints; cerci with a few long setae on the lower side, while all the other setae are short; last pair of legs with 3 long dorsal setae on the penultimate joint and 4 or 5 on the last joint: Austin, Texas.

S. pusilla Hansen. Length 1.7 mm.; antennae with 14 joints; last pair of legs with 2 long dorsal setae on the penultimate joint and 3 on the last joint: Austin, Texas.

Suborder 2. PAUROPODA.†

Minute myriapods in which the body consists of a head and 12 segments, the latter being covered in most cases by 6 large dorsal plates and bearing 9 pairs of legs, each of which has a single terminal claw; each antenna consists of 4 basal segments and 2 terminal branches, one of which is larger than the other and ends with 2 flagella and either a stalked or a sessile round knob; one pair of maxillae, which form an underlip; eyes absent; 4 or 5 pairs of long tactile bristles project from the sides of the body; heart and respiratory organs wanting; genital pores just behind the second pair of legs, being paired in the male and simple in the female; young born with only 3 pairs of legs: 2 families, 2 genera, and 6 species, 3 being American; they live in woody places, under stones, etc.

Family 1. PAUROPODIDAE.

Body elongate and cylindrical, with long legs projecting laterally beyond the trunk; color white; each dorsal plate with 2 transverse rows of bristles: 1 genus.

* See "Habits and Structure of Scutigerella Immaculata (Newport)," by S. R. Williams, Proc. Bost. Soc. Nat. Hist., Vol. 33, p. 461, 1907.

† See "A New Genus of Minute Pauropod Myriapods," by J. H. Ryder, Am. Nat., Vol. 13, p. 603, 1879. "The Morphology and Classification of the Pauropoda," by F. C. Kenyon, Tufts College Studies, No. 4, p. 77, 1895.

Pauropus Lubbock. With the characters above given: 2 species, 1 American.

P. huxleyi Lub. (*P. lubbocki* Packard) (Fig. 724). Terminal knob of antenna sessile or nearly so; length 1.3 mm.; width .35 mm.: Europe and eastern and central United States.

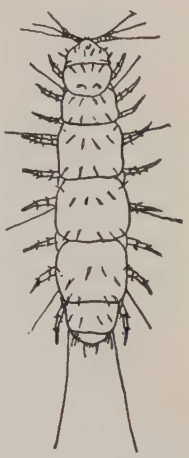

Fig. 724—*Pauropus huxleyi* (Kenyon).

Family 2. EURYPAUROPODIDAE.

Segmentation indistinct; 9 pairs of legs present; body very wide and flat, and tuberculate and spinose dorsally, with the head and the short legs concealed under it; color reddish; antennal knob on a long stalk: 1 genus and 3 species, 1 American.

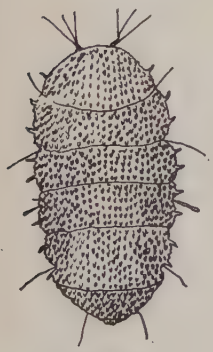

Fig. 725 *Eupauropus spinosus* (Kenyon).

Eurypauropus Ryder. With the characters above given.

E. spinosus Ryder (Fig. 725). Length 1.25 mm.; width .5 mm.: eastern and central United States; Europe.

Suborder 3. DIPLOPODA. (Chilognatha.)

The millipeds (Fig. 726). Usually elongate and cylindrical myriapods with 2 pairs of legs on most of the segments; with the exception of the first few and the last segments, each has been formed by the fusion of 2 somites, thus possessing 4 legs, 2 ganglia, 2 pairs of spiracles, and 2 pairs of openings in the heart; antennae short, mostly 7-jointed; but one pair of maxillae present, which are united to form an underlip called the gnathochilarium; an upper lip present in front of the mouth; integument often hard, containing calcium carbonate; legs of each pair spring from the ventral surface close together and near each leg is a spiracle; a row of the openings of stink glands usually present along the side of the body, which secrete an offensive gas, which in certain cases is hydrocyanic acid; tracheae of primitive structure, each spiracle opening into a bunch of usually unbranched tubes; gonads usu-

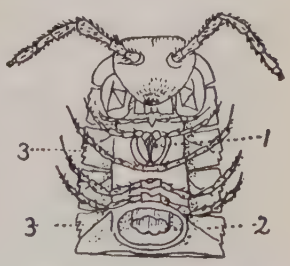

Fig. 726—Diagram of the front end of a diplopod (*Polydesmus*) (Latzel). 1, female genital pore; 2, intestine; 3, dorsal plate.

ally unpaired and in the hinder part of the body; the paired ducts leading to two openings in the second body segment; one or both pairs of legs in the seventh segment usually modified in structure in the male to serve as copulatory organs; the young larvae with but 3 pairs of legs and few segments: about 8 families and 125 American species, which are usually sluggish animals living under stones and in other dark, moist places, and feeding on decaying vegetable and animal matter, but also in some cases on living roots and thus often proving destructive in gardens.

Key to the families of *Diplopoda* here described:

a_1 Anus in terminal segment; maxillae forming a plate; integument hard; copulatory feet present.
b_1 Mouth parts suctorial and more or less like a proboscis....1. POLYZONIIDAE
b_2 Mouth parts not suctorial.
c_1 Segments 30 or more in number.
d_1 Both pairs of legs on seventh segment of male copulatory.
e_1 Stink glands present; anal segment rounded or produced into a spine. 2. JULIDAE
e_2 Stink glands absent; anal segment usually elongated into 2 slender papillae .....3. CRASPEDOSOMIDAE
d_2 Anterior pair of legs only on seventh segment of male copulatory. 4. LYSIOPETALIDAE
c_2 Segments 20 or 21; anterior pair of legs on seventh segment copulatory .....5. POLYDESMIDAE
a_2 Anus on the penultimate segment; maxillae leg-like; integument soft, with bunches of hairs; copulatory feet absent.....6. POLYXENIDAE

FAMILY 1. POLYZONIIDAE.

Body elongate, with a hard integument, and wide and more or less flattened, consisting of from 30 to 100 or more segments; mouth parts more or less rudimentary and prolonged to form a suctorial proboscis; row of stink glands on each side; both pairs of legs on the seventh segment copulatory: 4 American genera with about 5 species, all of which can roll themselves together so as to form a ball.

POLYZONIUM Brandt. First dorsal plate rounded in front and projecting to the base of the antennae, concealing nearly all of the ocelli, which are 2 to 4 in number; antennae close together; legs very short, the third segment being without them: 1 American species.

P. rosalbum (Cope). Color reddish-brown above, paler posteriorly and along the margins; antennae very dark, with 6 joints; 39 to 53 segments: central states, often common.

FAMILY 2. JULIDAE.

Body elongate, cylindrical, and with a hard integument, consisting of from 30 to 70 segments, the double pairs of legs beginning on the fifth; antennae on the sides of the head; both pairs of legs on the seventh segment of males copulatory; a row of stink glands on each side of the

body; third segment usually legless: 7 American genera and about 50 species, all of which can roll themselves together.

Key to the genera of *Julidae* here described:

a_1 Third segment without legs.
  b_1 Mandibular teeth 4.
    c_1 Only the ventral plates of the first 2 segments free.....1. JULUS
    c_2 All the ventral plates free.....2. NEMASOMA
  b_2 Mandibular teeth 10.....3. PARAJULUS
a_2 Third segment with legs.
  b_1 All 4 anterior segments with legs.....4. SPIROBOLUS
  b_2 Fourth segment without legs.....5. CAMBALA

1. JULUS L. Eyes, if present, composed of a number of ocelli; third segment without legs; first pair of legs of male 3-jointed, very small; antennae delicate; copulatory legs of male usually hidden; only the ventral plates of first segments free; mandibular teeth 4: about 10 American species.

Fig. 727 *Julus virgatus* —hind end of body (Wood).

J. virgatus Wood (Fig. 727). Body yellowish-brown, with a median and 2 lateral bands; eyes distant, composed of 25 to 40 ocelli on a side; segments 30 to 35; legs 50 to 65 pairs; last segment rounded; length 12 mm.; width 1 mm.: common all over the country, especially in meadows and gardens.

J. venustus Wood. Color reddish-chestnut, lighter in young specimens; segments 52 with usually two black dots on each side of each segment; last segment mucronate; length 2 cm.: common in eastern and central states.

2. NEMASOMA Koch. Similar to *Julus,* but all the ventral plates free: 2 American species.

N. minutum (Brandt). Body brown, with a lateral row of ovate black spots in each side, composed of 35 to 45 segments, 12 mm. long, .8 mm. wide; feet pale, not extending beyond the body; eyes distinct, with a dark band between them and with 8 or 9 ocelli on a side: common in eastern and central states.

3. PARAJULUS Humbert and Saussure. Eyes composed of numerous ocelli; third segment without legs, second pair very small; first pair in males 6-jointed; mandibular teeth 10; number of segments 40 to 70, last segment more or less prolonged into a spine: 13 American species.

P. impressus (Say). Body not hairy, chestnut brown, with a middorsal line and 2 lateral rows of black spots and composed of 45 to 55 segments, 32 mm. long and 2 mm. wide; 70 to 90 pairs of feet, sparsely hairy; the first pair very large; ocelli 40 to 60 on a side; terminal spine short: central and eastern states.

P. pennsylvanicus (Brandt). Body rough and hairy, dark brown, with a mid-dorsal line and 2 lateral rows of black spots, composed of 55 to 65 segments, 38 mm. long, 2 mm. wide; 100 to 112 pairs of pale feet, densely hairy, first pair large; ocelli 40 to 70 on a side; terminal spine small: common in the central and eastern states.

Fig. 728 *Parajulus canadensis* —hind end of body (Wood).

P. canadensis (Newport) (Fig. 728). Body not hairy, very dark brown, with 2 lateral rows of yellow spots, composed of 56 segments, 25 mm. long, 1.5 mm. wide; 86 to 93 pairs of very pale feet, sparsely hairy; terminal spine large, round, and curved; ocelli 43 to 50: northeastern states and Canada.

4. **Spirobolus** Brandt. All anterior segments with legs; mandibular teeth 10; antennae short and thick: about 12 American species, chiefly in the southern states and California.

S. marginatus (Say) (Fig. 729). Body dark brown with a reddish ring on each segment, smaller specimens greenish; feet and antennae reddish; composed of 53 to 57 segments; 10 cm. or less long and 1 cm. wide; 88 to 100 pairs of feet, extending beyond the sides of the body; eyes indistinct, composed of 30 to 40 ocelli on a side; antennae short, not reaching the hinder border of the first segment: common in the eastern and central states.

Fig. 729 *Spirobolus marginatus* (Wood).

5. **Cambala** Gray. Each eye composed of a single row of 4 to 6 ocelli; fourth segment without legs; first pair in males 6-jointed; mandibular teeth 6 or 7; number of segments 50 to 65; last segment rounded; dorsal plates of segments with sharp, parallel ridges: 1 species.

C. annulata (Say). Body long and slender; color yellowish-brown, with 2 lateral rows of dark brown spots; 70 to 112 pairs of legs; length 38 mm.; width 2 mm.: common in the eastern and central states.

Family 3. CRASPEDOSOMIDAE.

Like the *Julidae*, but without stink glands and with the terminal segment elongated into 2 slender papillae: 6 American genera with about 15 species.

Campodes Koch. Anterior pair of legs on eighth as well as both pairs on seventh segment copulatory; body covered with fine hairs: 1 species.

C. flavicornis Koch. Body yellowish-brown, with a light mid-dorsal line with darker spots, with about 30 segments, and 15 mm. long; eyes triangular and prominent; antennae slender and long: often common in the eastern and central states.

Family 4. LYSIOPETALIDAE.*

Like the *Julidae,* but with the first pair of legs only of the seventh segment copulatory: 1 American genus.

Lysiopetalum Brandt. Body long and slender, tapering gradually to the hinder end; seventh antennal joint conical and very short: 1 American species; several in Europe.

L. lactarium (Say) (Fig. 730). Body with about 60 segments and 115 pairs of legs, yellowish-brown in color with mottled darker spots and bands; eyes with 40 ocelli connected by a black band; length 35 mm.; width 2 mm.: common throughout the eastern and central states.

Fig. 730—*Lysiopetalum lactarium* (Wood). A, head; B, hind end of body.

Family 5. POLYDESMIDAE.

(Fig. 726). Body more or less elongate, broad and flattened, and with a hard integument, composed of 19 or 20 segments and with 28 to 31 pairs of legs; the dorsal plate of each segment prolonged laterally on each side to form a conspicuous wing; eyes absent; antennae long; a row of stink glands on each side, usually with a swelling around each; anterior pair of legs only copulatory on seventh segment of male: 9 American genera with about 50 species, all of which can roll themselves together.

Key to the genera of *Polydesmidae* here described:

a_1 Basal portion of leg without spines.
  b_1 Anal segment pointed behind.
    c_1 Dorsal plates flat.
      d_1 Each stink pore surrounded by a long, oval swelling; each segment with 2 or 3 transverse rows of tubercles.....1. Polydesmus
      d_2 Each stink pore surrounded by a round swelling; each segment with 4 or 5 rows of tubercles.....2. Scytonotus
    c_2 Dorsal plates convex and smooth.....3. Leptodesmus
  b_2 Anal segment quadrate and smooth, or nearly so.....4. Euryurus
a_2 Basal portion of legs with spines.....5. Fontaria

1. Polydesmus Latreille. Male with 30, female with 31 pairs of legs; each segment with 2 or 3 transverse rows of distinct tubercles; each stink pore surrounded by an elongated swelling; lateral plates large and horizontal in position: 9 American species.

P. serratus Say (*P. canadensis* Newport). Body brown, often reddish in color, about 37 mm. long; each dorsal plate with 2 rows of 4 rectangular tubercles in each; terminal spine of male copulatory appendage hook-shaped: common in the eastern and central states.

* See "A Revision of the Lysiopetalidae," by A. S. Packard, Proc. Am. Phil. Soc., Vol. 21, p. 177.

P. moniliaris Koch (*P. serratus* Wood) (Fig. 731). Body deep brown, about 20 mm. long; each dorsal plate with 3 rows of rectangular tubercles; terminal spine of male copulatory leg double: eastern states.

2. **Scytonotus** Koch. Each segment with 4 or 5 rows of tubercles; each stink pore surrounded by a round swelling: 3 American species.

S. granulatus (Say). Body brown, about 12 mm. long; lateral plates not large: eastern and central states; common.

3. **Leptodesmus** Saussure. Dorsal plates without tubercles and more or less convex, the body being rather narrow: 8 American species.

Fig. 731 *Polydesmus moniliaris* (Wood).

L. hispidipes (Wood). Color dark olive brown, sometimes with yellowish spots and a mid-dorsal black line; legs roughened, with closely set, stiff hairs; genital appendages of male short and thick, with a curved, hairy terminal spine: central states, being abundant towards the south.

4. **Euryurus** Koch. Dorsal plates smooth or with indistinct tubercles; anal segment quadrate and not sharp behind: 2 American species.

E. erythropygus Brandt (Fig. 732). Body 28 mm. long and 3.5 mm. wide, olive chestnut in color, with a median and a pair of lateral orange spots on each segment; terminal spine of male copulatory appendage curved, and forked at the end: common in the central states.

5. **Fontaria** Gray. Basal portion of the legs with spines; dorsal plates convex, with large lateral plates: 20 American species.

F. virginiensis (Drury) (Fig. 733). Body chestnut in color with lateral plates of yellow; lateral plates rounded in front, acute behind; terminal spine of male copulatory appendage curved and forked at the end and with a bristle springing from it: common in the central states.

Fig. 732 Fig. 733

Fig. 732—*Euryurus erythropygus* (Wood).
Fig. 733—*Fontaria virginiensis* (Wood).

F. coriacea Koch. Body dark chestnut with a yellowish border on each side; lateral plates very broad; terminal spine of male copulatory appendage large and with a corkscrew twist: often common in the central states.

Family 6. POLYXENIDAE.

Body minute, short, broad, with a soft integument, and a bunch of hairs on each side segment; the mandibles are entirely within the mouth

and the maxillae are leg-like; body with 11 segments with 13 pairs of legs; eyes present; no stink glands; no copulatory feet in the male; anus in penultimate segment: 1 genus.

Polyxenus Latreille. With characters given above: 1 species, which cannot roll itself together.

P. fasciculatus Say. Length 2.5 mm.; color pale brown; head broad, partly covered with hairs, with small eyes, and short thick antennae; feet white: under stones and bark; the southern states; Long Island; not common.

Order 2. CHILOPODA.*

The centipeds (Fig. 734). Elongate and flattened myriapods with one pair of legs on a segment, *Scutigera* forming an apparent exception; number of leg-bearing segments varies from 15 (*Lithobius, Scutigera*) to 173 (*Geophilidae*); antennae long and at least 12-jointed; 2 pairs of maxillae present, the first pair not being united, the second being prominent palp-like structures, the basal parts of which are joined in the median line; a paired upper lip in front of the mandibles; legs usually long, those of each pair being widely separated from each other on the ventral surface; the first pair modified to form a pair of hook-like jaws called the maxillipeds, which project forwards beneath the head and are prehensile organs, each being provided with a poison gland; the broad bases of the maxillipeds are joined in the middle line to form a lower lip; tracheae similar to those of insects, consisting of branching and usually anastomosing trunks, the spiracles being situated on the side of the body on certain of the segments; genital glands open to the outside in the penultimate segment; the young animals possess all their legs at birth in the *Geophilidae* and *Scolopendridae,* and 7 pairs in the *Lithobiidae* and *Scutigeridae:* about 800 species, which are active animals feeding on live animals and killing their prey with the poison of the maxillipeds; certain of the tropical *Scolopendridae* can inflict a wound which is dangerous to man; 4 families.

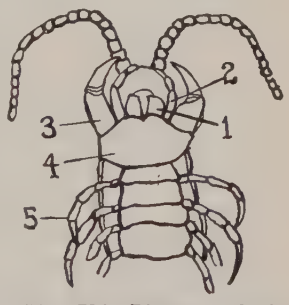

Fig. 734—Diagram of the front end of a chilopod (McMurrich). 1, first maxilla; 2, second maxilla; 3, maxilliped; 4, first somite; 5, first leg, on second somite.

* See "The Chilopoda of California," by R. V. Chamberlain, Pomona Jour. Ent., Vol. 4, 1912. "Notes on Geophiloidea from Iowa," etc., by same, Canad. Ent., Vol. 44, 1912. "The Geophiloidea of the Southeastern States," by same, Bull. Mus. Comp. Zool., Vol. 54, 1912. "The North American Chilopods and Diplopods," by same, Ann. Ent. Soc. Am., Vol. 5, 1912.

Key to the families of *Chilopoda:*

a_1 Dorsal plates 15 or more.
  b_1 Pairs of legs 21 or more.
    c_1 Pairs of legs 31 or more; no eyes.....1. GEOPHILIDAE
    c_2 Pairs of legs 21 or 23.....2. SCOLOPENDRIDAE
  b_2 Pairs of legs 15.....3. LITHOBIIDAE
a_2 Dorsal plates 8; 15 pairs of very long legs.....4. SCUTIGERIDAE

FAMILY 1. GEOPHILIDAE.

Body very long and slender, with 31 to 173 segments, each composed of 2 unequal subsegments, with an equal number of pairs of legs and ventral plates; number of pairs of spiracles usually 2 less than the pairs of legs; antennae 14-jointed; eyes absent; young born with the full number of legs; habits relatively sluggish: about 5 American genera and 50 species.

1. GEOPHILUS Leach. Number of segments 31 to 93; first pair of maxillae with a pair of palp-like projections; dorsal plates with 2 longitudinal grooves: about 20 American species.

G. rubens Say (*G. cephalicus* Wood). Body wide, especially the head, about 45 mm. long, with 47 to 53 pairs of legs; color orange anteriorly, dark olive over a greater part of the body, with a broad, double, black median line; last ventral plate wide; anal legs hardly longer than the others: common throughout the eastern and central states.

G. umbraticus (McNeill). Pairs of legs 49, with long hairs, the anal legs being slender and but little modified; color light orange in front and behind and fuscous between; body hairy above; length 21 mm.: central states, often very common.

2. LINOTÆNIA Koch. Number of segments 39 to 70; head very small; first pair of maxillae without palp-like projections and with the exterior part 2-jointed; anal legs 6-jointed; claw of prehensile legs with a basal tooth: 13 American species.

L. fulva (Sager). Body smooth, about 20 mm. long, tapering anteriorly, and with 47 pairs of legs, yellowish-orange in color; antennae thread-like; basal joint of last pair of legs in male much thickened: central states, often common.

L. ruber (Bollman). Body about 35 mm. long and 2 mm. wide, with 67 to 73 pairs of legs; color bright red in life, yellowish in alcohol; first pair of legs shorter than the second; last pair not much longer than the first and thickened: central states, often common.

FAMILY 2. SCOLOPENDRIDAE.

Body elongate, with either 21 or 23 segments and an equal number of pairs of legs and ventral plates; number of spiracles 9, 10, or 11; antennae with 17 to 31 joints; eyes, when present, consist of 4 ocelli each;

young born with the full number of legs: active animals found chiefly in the warmer parts of the earth, where certain species attain great size and are dangerous to man, although it seems doubtful if the bite of any of them is fatal; 5 American genera and about 20 species. The largest known centiped is *Scolopendra gigantea* L., which attains a length of 27 cm. or more, and is found in the East Indies.

Key to the genera of *Scolopendridae* here described:

a_1 Pairs of legs 21.
  b_1 Eyes present.....1. SCOLOPENDRA
  b_2 Eyes absent.
    c_1 Anal legs not thick.....2. CRYPTOPS
    c_2 Anal legs very thick and short.....3. THEATOPS
a_2 Pairs of legs 23.....4. SCOLOPOCRYPTOPS

1. SCOLOPENDRA L. Number of pairs of legs 21; 9 pairs of slit-like spiracles; 4 ocelli on each side; dorsal plate of head heart-shaped and extending back over the first segmental plate: over 50 species, about 10 American, which are found principally in the south.

S. morsitans L. Body 65 mm. and more long and greenish in color; antennae green; lateral edges dark green; legs short, not longer than the 3 terminal body segments: cosmopolitan; rather southerly in America.

S. heros Girard (*S. castaniceps* Wood) (Fig. 735). Body 10 cm. long or more, yellow and green in color; antennae 25-jointed; penultimate joints of legs armed with spines; first dorsal plate with a transverse suture; anal legs long, with 17 to 25 spines: Mexico and the southern states, extending north to Kentucky.

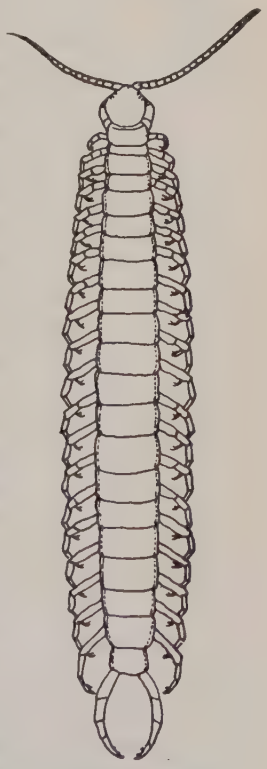

Fig. 735—*Scolopendra heros* (Wood).

2. CRYPTOPS Leach. Number of pairs of legs 21; 9 pairs of slit-like spiracles; antennae 17-jointed; eyes absent; anal legs not thickened: over 20 species, 1 or 2 being American.

C. hyalina Say. Body about 15 mm. long, smooth and very flat, with reddish-brown head and 2 black internal longitudinal lines: eastern and central states, north to New Jersey and Indiana, often common.

3. THEATOPS Newport. Similar to *Cryptops* but with the anal legs very thick and short and with the last dorsal plate twice as large as the preceding: 2 American species.

T. postica (Say) (Fig. 736). Body about 45 mm. long, reddish in color; anal legs close together and parallel, with the tips crossing, their basal position without spines: eastern and central states, north to Virginia and Illinois, often very common.

Fig. 736 *Theatops postica* (Wood).

4. **Scolopocryptops** Newport. Number of legs 23; 10 or 11 pairs of spiracles; eyes absent; cephalic dorsal plate extends back over the first segment, which has no transverse suture; antennae 17-jointed: 4 American species.

S. sexspinosa (Say). Body 65 mm. long, reddish in color; feet yellow; antennae yellow and hairy; basal portion of anal legs with 2 large spines (inner one sometimes atrophied in northern specimens); cephalic plate marginate; anterior margin of the lower lip (basal portion of maxillipeds) nearly straight, not toothed: entire United States, often very common.

Family 3. LITHOBIIDAE.

Body with 15 leg-bearing segments, of which 9 are large and 6 (segments 2, 4, 6, 9, 11, and 13) small, the anterior segment bearing the maxillipeds and the anal segment being without appendages; with 15 pairs of legs, in the coxae of the last 4 pairs of which are the openings of coxal glands; eyes composed of usually many ocelli; maxillary palp 3-jointed; young born with 7 pairs of legs: 10 genera, with about 250 species, about 50 species being American.

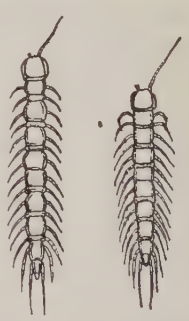

Fig. 737 Fig. 738

Fig. 737—*Lithobius forficatus* (Wood).
Fig. 738—*Lithobius multidentatus* (Wood).

Lithobius Leach. Spiracles on segments 3, 5, 8, 10, 12, 14, and sometimes also 1; coxa of maxillipeds with 2 to 8 teeth on each side; antennae with usually 20 to 50 joints: over 200 species, about 47 American.

L. forficatus (L.) (Fig. 737). Body about 28 mm. long, anal legs 10 mm. long; color brownish or yellowish; antennae half as long as the body, with 33 to 43 joints; ocelli 23 to 48 in number; posterior angles of dorsal plates 9, 11, 13 elongated: the entire country; Europe; South America; often very common.

L. multidentatus Newport (Fig. 738). Body about 25 mm.; anal legs 10 mm. long; color brown; antennae short, with 19 to 23 joints; ocelli 27 to 35 in number; posterior angles of dorsal plates 6, 7, 9, 11, 13 elongated: eastern and central states; common.

Family 4. SCUTIGERIDAE.

Body relatively short, consisting of about 15 segments, the dorsal surface of which is covered by 8 large plates; 15 ventral plates and 15 pairs of very long legs, the last pair being longer than the body and used as anal feelers; antennae and maxillary palps very long; eyes large and composite; spiracles a row of 7 mid-dorsal slits; young born with 7 pairs of legs: 13 genera and 30 species, 2 being American, which are found in damp places in houses, especially in cellars, where they feed on cockroaches and other insects.

Fig. 739.—*Scutigera forceps* (Wood).

Scutigera Lamarck. With the characters above given.

S. forceps (Rafinesque) (Fig. 739). Body about 25 mm. long, light brown in color, with 3 longitudinal dark stripes; last pair of legs 50 mm. long: western and central states, very common towards the south; in New England as far north as Boston.

PHYLUM 6.

MOLLUSCA.*

Bilaterally symmetrical, unsegmented animals in which the body is usually encased in a calcareous shell, and is made up of four parts, the visceral mass, the head, the mantle, and the foot (Fig. 740).

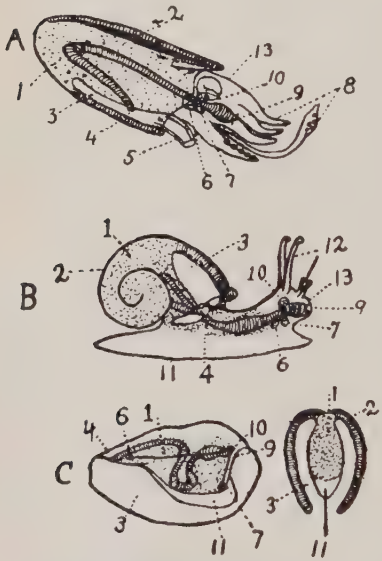

Fig. 740—Diagrams of the types of molluscan structure (Hertwig). A, the cephalopod type; B, the gastropod type; C, pelecypod type. 1, visceral mass; 2, shell and mantle; 3, mantle cavity; 4, anus; 5, siphon; 6, visceral ganglion; 7, pedal ganglion; 8, arms on head; 9, mouth; 10, cerebral ganglion; 11, foot; 12, tentacles; 13, head.

External Structure.—The visceral mass (1), which forms the greater part of the body, contains the viscera, closely compacted together. At its anterior end is the head (13), with the mouth and the most important organs of special sense, and from its dorsal side the mantle falls as an extensive integumental fold over its sides and more or less completely envelopes it (2), while from its ventral side extends the foot (11), a muscular mass by means of which the animal moves.

In the pelecypods and scaphopods the head is wanting, the mouth being at the forward end of the visceral mass. In the same animals also the mantle is a double fold, one half falling to the right and the other to the left of the

* See "Manual of Conchology," by G. W. Tryon and H. A. Pilsbry, Philadelphia, 1878 to date. "Manual de Conchologie," etc., by P. Fischer, Paris, 1880-1887. "Structural and Systematic Conchology," by G. W. Tryon, Jr., 1882. "Mollusca," by J. S. Kingsley, Stand. Nat. Hist., Vol. 1, 1888. "A Preliminary Catalogue of the Shell-bearing Mollusks," etc., by W. H. Dall, Bull. No. 37, U. S. Nat. Mus., 1889. "Mollusca," by H. Simroth, Bronn's Kl. u. Ord., Vol. 3, 1892 to date. "Mollusks," by A. H. Cooke, Camb. Nat. Hist., Vol. 3, 1895. "Molluskan Fauna of Philadelphia," by M. Schick, Nautilus, Vol. 8, p. 133, 1895. "Molluscan Fauna of Western New York," by F. C. Baker, Trans. Acad. Sci., St. Louis, Vol. 8, p. 71. 1898. "West American Shells," by J. Keep, San Francisco, 1904. "Mollusca," by Paul Pelseneer in "A Treatise on Zoology," edited by E. R. Lankester, 1906. "The Shell-book," by Julia E. Rogers, 1909. "A Biological Survey of Woods Hole and Vicinity," by F. B. Sumner and others, Bull. Bur. Fish., Vol. 31, 1911.

visceral mass; in other mollusks, on the other hand, the mantle is a single fold covering the visceral mass on all sides as a thimble covers the finger.

The outer surface of the mantle secretes the shell, which may be regarded as the cuticula and is usually charged with calcium carbonate, while the space between the mantle and the visceral mass is called the mantle cavity (3). This space is important in that it contains the gills, and that the digestive, excretory, and reproductive organs usually empty their products into it. A mantle is wanting in many mollusks, which are also without a shell. Other mollusks which have a mantle may lack the shell; in many slugs and also in the squids the shell is buried in a pocket of the mantle and is not on the surface. The shell thus takes the form of the mantle, and may be bivalved or univalved,

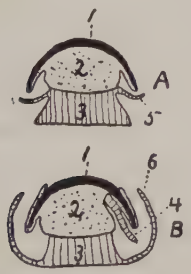

Fig. 741

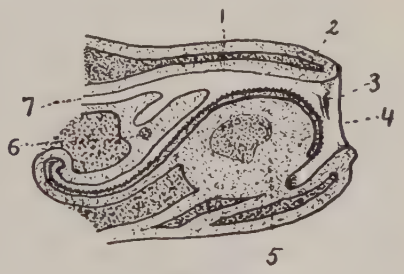

Fig. 742

Fig. 741—Diagrammatic cross sections of gastropods. A, a prosobranch with epipodia; B, an opisthobranch with parapodia (Lang). 1, shell; 2, visceral mass; 3, foot; 4, gill; 5, epipodium; 6, parapodium. Fig. 742—The mouth and pharynx with the radula of a snail (Lang). 1, pharynx; 2, radula; 3, jaw; 4, mouth; 5, tongue; 6, opening of salivary glands; 7, œsophagus.

and spiral or cone-shaped. The shell is usually composed of three layers, the inner mother-of-pearl layer which is secreted by the general surface of the mantle, and the middle columnar and outer periostracal layers which are secreted by its lower margin.

The foot is flat and used for creeping by the chitons, gastropods, and a few pelecypods, this probably being its primitive form and use. It may have a variety of forms in other mollusks and the following divisions may in certain cases be distinguished in it: the propodium or forward and the metapodium or hinder portion, the parapodia or lobe-like extensions of the sole (Fig. 741, 6), and the epipodium, a ridge along the side (Fig. 741, 5).

Internal Structure.—Correlated with the compactness of the visceral mass is the small extent of the cœlom, which is usually confined to the pericardial space and the cavities of the gonads. The mouth opens into a muscular pharynx (Fig. 742) in all mollusks except pelecypods,

which contains a rasping organ called the radula: an œsophagus, a stomach with a large liver, and an intestine form the remainder of the alimentary canal. The radula (Fig. 742, 2) is a chitinous ribbon set with minute calcareous teeth in regular longitudinal and transverse rows which works over a muscular tongue. The teeth vary in number from one in *Chætoderma* to thousands in many snails and are often of great importance in classification, inasmuch as in each species they have usually a characteristic arrangement and shape. In each transverse row there is typically a single central tooth, on each side of which are one or more laterals, and at the side of these, one or more marginals (Fig. 830). The respiratory system consists typically of a pair of ctenidia, or comb-shaped gills in the mantle cavity (Fig. 821, A). They are modified in various ways among the different mollusks and in pulmonate snails, nudibranchs, and some others, are wanting, respiration being performed by lungs or by other organs. The circulatory system consists of a heart, arteries which distribute the blood to lacunar spaces in the tissues, and veins which take it from these spaces to the kidneys and respiratory organs and thence to the heart. The heart consists typically of a muscular ventricle (Fig. 821, 3), which drives the blood through the arteries (4), and one or two pair of auricles (2), which receive it from the gills. Snails with but one gill or lung have also but one auricle. The heart thus always contains arterial blood. The excretory system consists typically of paired sac-like kidneys (nephridia) which open into the mantle cavity at their hinder ends (Fig. 746, 14) and into the pericardial space (the cœlom) at the forward. The nervous system contains four principal pairs of ganglia with nerves joining them. These are the cerebral ganglia (Fig. 740, 10), just above the œsophagus, which form the brain, the pedal (7), the visceral (6), and the pleural ganglia. The cerebral ganglia are joined with the pedal and visceral ganglia by nerve connectives; in gastropods the pleural ganglia lie in the course of the cerebro-visceral connectives; in pelecypods they are joined with the cerebral and in cephalopods with the visceral ganglia.

The most important special sense organs consist of camera-obscura eyes and tentacles usually on the head, but in the pelecypods in the edge of the mantle when present, lithocysts in the foot, and osphradia, organs of taste or smell, near the base of the gills.

The gonad is single in all mollusks except the pelecypods and *Solenogastres,* in which it is paired; the ducts leading from the gonad open usually into the mantle cavity, and are either paired or single. The sexes are usually separate, although numerous hermaphrodites (pulmonates, opisthobranchs) occur. The young animal in most

cases goes through a metamorphosis after birth, the characteristic molluscan larva being called the veliger larva. A few mollusks are viviparous.

Distribution and Habits.—The majority of mollusks are aquatic animals, most of them living in the sea. Many species live in fresh water and many have become terrestrial animals, although the latter usually require a moist environment. The pelecypods, which have no radula, feed on minute organisms suspended in the water. The majority of the mollusks with a radula feed on vegetal substances; all the cephalopods, however, and very many gastropods are predacious animals and a few of the latter are parasitic. The cephalopods are active and powerful beasts of prey and include among their number the largest and most highly developed invertebrate animals.

History.—Although mollusks have been well known from the earliest times on account of their conspicuous shells, it was not until the time of Cuvier that the foundation of the modern classification was laid. Guided by his own extensive anatomical studies and those of Poli and other contemporaries, Cuvier, in 1795, subdivided the class into the three orders of *Cephalopoda, Gasteropoda,* and *Acephala,* which is the foundation of their modern arrangement. Linnæus had made the mollusks one of his four subdivisions of *Vermes,* including among them only the slugs, squids, octopods, and other soft, shell-less animals. The shell-bearing mollusks he included in the class *Testacea,* which he subdivided into *Bivalvia, Univalvia,* and *Multivalvia.*

The first students of mollusks in America, as elsewhere, were the collectors of shells. The first scientific descriptions of importance were published by Thomas Say in 1817, who between that date and 1834, when he died, described a large number of species. C. S. Rafinesque, during almost the same period, also described large numbers of species, especially of fresh-water and land mollusks. It was by these two men and certain of their contemporaries and immediate followers, notably T. A. Conrad and Isaac Lea, that the foundations of the present knowledge of American mollusks were laid. Of the many students of mollusks of the middle of the century Gould, Stimpson, and A. and W. G. Binney are especially to be mentioned. Of late years especially noteworthy is the publication by the Academy of Natural Sciences in Philadelphia of the Manual of Conchology, a monographic work in many volumes which will cover the entire field. It was begun in 1878 by G. W. Tryon and is being continued by H. A. Pilsbry.

The phylum *Mollusca* contains over 60,000 living species and a very large number of fossil ones, it being the largest phylum of animals except the *Arthropoda:* they are grouped in 5 classes.

Key to the classes of *Mollusca:*

a_1 No distinct head present.
  b_1 Shell when present not bivalve.
    c_1 Body either naked or with shell consisting of 8 plates.....1. AMPHINEURA
    c_2 Cylindrical shell present.....2. SCAPHOPODA
  b_2 Bivalve shell present.....4. PELECYPODA
a_2 Distinct head present.
  b_1 Head with 1 or 2 pairs of tentacles; shell coiled or conic..3. GASTROPODA
  b_2 Head with long arms.....5. CEPHALOPODA

CLASS 1. AMPHINEURA.*

Bilaterally symmetrical mollusks, worm-like in appearance and with usually an inconspicuous head. The mouth is at the forward and the anus at the hinder end of the body, and on either side are the gills and the nephridial pores. The mantle is not extensively developed but consists of a slight fold extending from the sides and the hinder end of the body, enclosing a narrow mantle cavity (Fig. 746, 5). The integument of the back is thick and contains calcareous spicules or is covered with scale-like plates. A radula is usually present. The nervous system (Fig. 745) is very primitive in form, consisting of an œsophageal ring and four longitudinal nerves, two pedal, which innervate the foot, and two pallial, which pass along the mantle furrow; these may or may not contain definite ganglia.

History.—The class *Amphineura* was formed in 1877 by von Ihering, who maintained, as Huxley and Leuckart had already done, that *Chiton* was related to *Chætoderma,* which, until then, had been placed among the *Gephyrea,* and to *Neomenia,* whose position in the system had been very uncertain, but he placed the new class among the worms. *Chiton* was first studied by Cuvier, although it had been long known, who placed it beside *Patella* among the *Prosobranchiata,* where it remained almost down to the present day. Gegenbaur in 1878 erected the group *Solenogastres,* which he placed among the worms. In 1881 Spengel brought the *Amphineura* of von Ihering among the *Mollusca,* where they have since remained as their most primitive representatives. The modern arrangement of the group is due largely to Pilsbry and Simroth.

The *Amphineura* are all marine, living in most cases on the bottom, near the shore, or in moderate depths. The class contains two orders, with about 630 species.

Key to the orders of *Amphineura:*

a_1 No shell present.....1. APLACOPHORA
a_2 Shell present.....2. POLYPLACOPHORA

* "Amphineura," by H. Simroth, Bronn's Klass. u. Ord., Vol. 3, 1892.

Order 1. APLACOPHORA.* (Solenogastres.)

Body worm-like, being more or less cylindrical and usually elongate, and without a shell. The exceptionally thick cuticula contains calcareous spicules which sometimes project above the surface and represent the shell of the higher mollusks. On the ventral surface, except in *Chætoderma,* is a median longitudinal groove representing a rudimentary mantle cavity, the two sides of which are formed by the mantle-folds. Within this groove lies a ciliated ridge which represents the rudimentary foot. At the hinder end of the body this groove widens to form the cloacal cavity, in which are the anus, the two kidney pores, and the two gills.

The mouth opens into a pharynx in which a radula and salivary glands are usually present. The alimentary tract is straight. The nervous system is more highly developed than in *Chiton,* and has a distinct brain and numerous ganglia. The heart lies in a large pericardium at the hinder end of the body; this cavity represents the cœlom and communicates with the cloacal cavity by means of a pair of nephridial tubes. The gonads are paired and, except in *Chætoderma,* hermaphroditic. They are sac-like in structure and lie in front of the pericardium, into which they open. Their products pass into the pericardium and through the nephridia to the outside.

The *Solenogastres* are marine animals which live on or near the bottom in from 20 to 1,000 fathoms, in various parts of the world. Many species live on and among hydroids; others feed on crustaceans and many on plants.

The order contains 2 suborders, 13 genera, and about 30 species.

Key to the suborders of *Aplacophora:*

a_1 Mid-ventral groove present.....1. Neomeniina
a_2 No mid-ventral groove.....2. Chætodermatina

Suborder 1. NEOMENIINA.

Head and cloaca but little or not at all developed; mid-ventral groove present, at the forward end of which is a large gland; gills simple, sac-like evaginations of the cloaca and not feathered; animals hermaphroditic; nephridia unite and open to the outside through a single median pore beneath the anus; radula sometimes wanting; intestine with lateral pockets: 4 families and about 27 species.

Family 1. NEOMENIIDAE.

Body short and thick, with both ends alike; cloaca and mouth ventral, the former with a row of short respiratory papillae around its edge;

* See "Aplacophora," by H. A. Pilsbry, Man. of Conch., Vol. 17, 1892.

body covered with spicules, also with papillae; no radula present, the pharynx being protrusile: 1 genus; North Atlantic, Mediterranean Sea, and West Indies.

Neomenia Tullberg. With the characters of the family: about 4 species.

Fig. 743—*Neomenia carinata* (Cambridge Natural History).

N. carinata Tull. (Fig. 743). Body 2 to 3 cm. long and half as thick; back with a keel: North Atlantic.

Family 2. PRONEOMENIIDAE.

Body elongate, 9 to 14 times as long as thick; radula present; body covered with spicules: 4 genera.

Proneomenia Hubrecht. With the characters of the family: 2 species.

P. sluiteri Hub. Length 10 to 14 cm.: Arctic seas.

Suborder 2. CHÆTODERMATINA.

Mouth and cloaca terminal; head end and hinder end set off by constrictions; body cylindrical, without ventral groove, and covered with spicules; 2 feathered gills present; sexes separate: in the North Atlantic and the Pacific Oceans, burrowing in the mud; 2 genera.

Chætoderma Lovén. With the characters of the suborder: 3 species.

C. nitidulum Lov. (Fig. 744). Length 25 mm.; width 2 mm.: coast of Scandinavia and northern America; Gulf of Maine; in 100 fathoms.

Order 2. POLYPLACOPHORA.* (Chitons.)

Body from 10 mm. to 15 cm. in length, elliptical in shape, convex dorsally and flattened ventrally, and bearing on its dorsal surface a longitudinal row of eight calcareous plates or valves (Fig. 745). These plates possess characteristic form and markings and usually overlap posteriorly. They are composed of two distinct layers, the lower layer, the anterior portion of which extends forwards beneath the overlapping valve in front of it and is called the articulamentum, and the exposed layer, which is the tegmentum. They are surrounded and kept in place by a muscular integumental fold called the girdle, the portions concealed by the girdle being called the insertion plates. In *Cryptochiton* the girdle entirely covers the shell, and in several other genera it almost covers

* See "On Certain Limpets and Chitons from the Deep Waters of the Eastern Coast of the United States," by W. H. Dall, Proc. U. S. Nat. Mus., Vol. 4, p. 400. "Polyplacophora," by H. A. Pilsbry, Man. of Conch., Vol. 14 and 15, 1892. "Chitons Collected by Dr. Harold Heath," etc., by H. A. Pilsbry, Proc. Acad. Nat. Sci., 1898, p. 287.

it. The girdle varies much in character, its upper surface being either horny, covered with scales, or densely beset with spines. The foot is usually broad and flat, and is both a creeping surface and a sucker to attach the animal to the rocks; in a few forms the foot is much reduced

Fig. 744

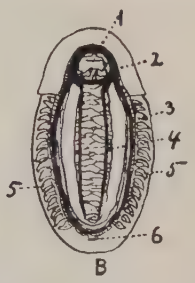

Fig. 745

Fig. 744—*Chætoderma nitidulum* (Cambridge Natural History). 1, mouth; 2, anus. Fig. 745—*Chiton squamosus*. A, dorsal aspect; B, diagram showing mouth (1), brain (2), pleurovisceral nerve chord (3), pedal nerve chord (4), gills (5), and anus (6).

and narrow, especially in certain vermiform species. The mantle (Fig. 746) is a fold which projects over the side of the foot enclosing a deep furrow along each side and at the hinder end of the body, which is the mantle cavity (5). In this cavity at the sides of the body are from 6 to 80 pairs of gills (6) and the genital and kidney pores, which are also paired. The mouth is at the forward and the anus at the hinder end. The head is rudimentary and tentacles are absent. Special sense organs are poorly developed, the most important being peculiar sense buds called æsthetes, which are present in definite groups in the shell; in certain species these organs are modified to form eyes.

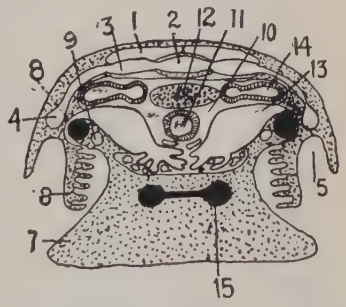

Fig. 746—Diagram of a cross section of a chiton (Lang). 1, pericardium; 2, ventricle; 3, auricle; 4, branchial vein; 5, mantle cavity; 6, gills; 7, foot; 8, pleurovisceral connectives; 9, branchial artery; 10, cœlom; 11, intestine; 12, gonad; 13, 14, nephridium; 15, pedal nerve chords.

The mouth opens into the pharynx, in which a radula is present; a pair of salivary glands join the pharynx. The digestive tract is made up of a short œsophagus, a stomach with a pair of livers, and a long coiled intestine. The nervous system (Fig. 745) is characterized by the lack of definite ganglia, except two small pairs near the pharynx, most of the ganglion cells being distributed throughout the larger nerves. The heart consists of a tubular ventricle (Fig. 746, 2) and a pair of auricles (3), and lies in a pericardium (1), which represents the hinder

part of the cœlom and communicates with the mantle cavity by means of the extensive nephridia (13, 14). The sexes are separate, the gonad communicating with the mantle cavity by a pair of ducts which join it in front of the nephridial pores. The eggs are sometimes laid in a common jelly which is attached to the rocks, or they may be attached separately or in small groups. *Chiton polii* retains its eggs in the mantle cavity until they hatch. The young are born as trochophore larvae.*

The *Polyplacophora* are found in all parts of the world, occurring chiefly in shallow water, although a few species live in the deep sea. They attach themselves to rocks, shells, corals, etc., feeding on diatoms and other plants. In the West Indies and other places they are an article of food, the foot being called sea beef. About 600 species are known, grouped in 3 suborders.

Key to the suborders of *Polyplacophora:*

a_1 Valves without insertion plates.....1. Eoplacophora
a_2 All valves with insertion plates.
b_1 Margin of insertion plates not pectinate.....2. Mesoplacophora
b_2 Margin of insertion plates pectinate.....3. Teleoplacophora

Suborder 1. EOPLACOPHORA.

Valves of large size, the anterior and posterior ones similarly articulated; insertion plates absent, except in certain cases on the anterior valve, and unslit: 1 family.

Family LEPIDOPLEURIDAE.

With the characters of the suborder: 4 genera.

Hanleyia Gray. Insertion plates wanting on all valves of the shell but the anterior one, and here they are unslit, but roughened; girdle with spines: 3 species.

Fig. 747 *Hanleyia mendicaria* (Gould).

H. mendicaria (Mighels and Adams) (Fig. 747). Shell grayish with a red margin, elliptical; surface with elevated dots, without concentric striae; gills posterior, about 15 on a side; length 27 mm.; breadth 15 mm.: northern New England, in shallow water.

Suborder 2. MESOPLACOPHORA.

All the valves with insertion plates, either the first alone or the first 7 of which are slit, and with smooth or roughened but not pectinate margins; eyes absent: 4 families.

* See "Contributions to the Embryology of Chiton," by M. M. Metcalf, Johns Hop. Univ., Stud. from Biol. Lab., Vol. 5, p. 249, 1893.

Key to the families of *Mesoplacophora* here described:

a_1 Tegmenta of the valves fully exposed.
  b_1 Last valve without a posterior sinus.....1. ISCHNOCHITONIDAE
  b_2 Last valve with a posterior sinus.....2. MOPALIIDAE
a_2 Tegmenta more or less reduced or covered by the girdle.
  3. ACANTHOCHITONIDAE

FAMILY 1. ISCHNOCHITONIDAE.

Valves of large size and exposed, the anterior and posterior ones similarly articulated; insertion plates smooth or nearly so and slit into teeth which project outwards: 12 genera, containing some of the commonest species along our shores.

Key to the genera of *Ischnochitonidae* here described:

a_1 No radiating ribs on the anterior valve.
  b_1 Girdle smooth, without scales or hairs.....2. TONICELLA
  b_2 Girdle not smooth.
    c_1 Girdle hairy.....1. CHÆTOPLEURA
    c_2 Girdle granulated.....3. TRACHYDERMON
    c_3 Girdle covered with scales.....4. ISCHNOCHITON
a_2 Anterior valve with radiating ribs.....5. NUTTALLINA

Fig. 748

Fig. 749

Fig. 750

Fig. 748—*Chætopleura apiculata* (Gould). Fig. 749—*Tonicella marmorea* (Gould). Fig. 750—*Trachydermon ruber* (Gould).

1. CHÆTOPLEURA Shuttleworth. Umbo of posterior valve central or anterior; girdle leathery and more or less hairy: 16 species.

C. apiculata (Say) (Fig. 748). Shell oval, light buff or ashen, sometimes reddish in southern specimens, keeled, central areas with longitudinal rows and lateral areas and end valves with irregularly scattered tubercles; gills, 24 on a side, extending almost to anterior end; length 17 mm.; breadth 10 mm.: Cape Cod to Florida, very common in shallow water.

2. TONICELLA Carpenter. Umbo of posterior valve anterior; girdle leathery and smooth, without scales or hairs: 7 species.

T. marmorea (Fabricius) (Fig. 749). Shell oval, buff-colored, closely speckled with dark red; surface densely, microscopically granulated; gills 20 to 25 on a side, extending three-quarters the length of the foot; length up to 40 mm.; breadth 24 mm.: circumpolar, south to Massachusetts Bay and to Aleutian Islands; Europe.

T. lineata (Wood). Shell rather low, light reddish in color; surface not granulated and shining; gills as in *T. marmorea;* length 37 mm.; breadth 20 mm.: Pacific coast from Monterey to Bering Strait.

3. **Trachydermon** Carpenter. Girdle covered with minute granules or scales: several species.

T. albus (L.). Shell elevated, minutely granulated, keeled; anterior valve semicircular; color whitish, sometimes shading into a light orange on each valve; interior white; length 15 mm.; breadth 7 mm.: circumpolar, south to Cape Cod; Pacific coast; Europe; low-water mark to 337 fathoms, often abundant.

T. ruber (L.) (Fig. 750). Shell smooth, elevated, microscopically reticulated, buff in color, marbled with reddish; 12 mm. long and 7.5 mm. wide; interior bright pink: circumpolar, south to Long Island Sound and Sitka; Europe; from low water mark to 80 fathoms; rare south of Cape Cod.

4. **Ischnochiton** Gray. Girdle covered with imbricating scales: numerous species.

I. magdalenensis (Hinds). Shell elongate and rather narrow, faintly mottled with olive on a light ground; central areas pitted; lateral areas and end valves with radiating lines; length 75 mm.; breadth 30 mm.: Monterey, California, to Magdalena Bay.

Fig. 751 *Nuttallina californica* (Keep).

5. **Nuttallina** Carpenter. Valves exposed, granulated, the lateral areas having 2, the head valve numerous low radiating ribs; girdle varying from spiny to scaly; umbo behind the middle: several species.

N. californica (Nuttall) (Fig. 751). Shell more than twice as long as wide, dark brown in color, with whitish streaks; median valves strongly beaked with a smooth rounded dorsal ridge; girdle covered with minute spines; length 37 mm.; breadth 15 mm.: coast of Oregon, Washington, and California.

Family 2. MOPALIIDAE.

Valves of large size on a broad body; each intermediate valve with a single slit; posterior valve with a median sinus; insertion plates on all the valves; girdle hairy, never scaly; gills extend the length of the foot: 3 genera; Pacific Ocean.

Mopalia Gray. Valves exposed; insertion plate of anterior valve slit into nearly smooth teeth; insertion plate of posterior valve with an oblique slit on each side: 5 species, all on Pacific coast.

M. muscosa (Gould). Shell oval, brownish in color, but sometimes bright green or red, anterior valve having about 10 radiating ribs; length 50 mm.; breadth 3.8 mm.: coast of Washington, Oregon, and California, between tide lines.

Family 3. ACANTHOCHITIDAE.

Shell reduced and more or less covered by the smooth or hairy (never scaly) girdle: 6 genera.

Key to the genera of *Acanthochitidae* here described:

a_1 Shell not completely covered.
b_1 Tegmenta bottle-shaped; last valve with a median sinus....1. Katharina
b_2 Tegmenta heart-shaped; last valve rounded.....2. Amicula
a_2 Shell completely covered.....3. Cryptochiton

1. Katharina Gray. Valves two-thirds covered by the girdle, the exposed portion divided into dorsal and side areas; insertion-plates sharp and very long, that of the head valve with 7 to 8 irregularly placed slits; gills long and extending the whole length of the foot: 1 species.

K. tunicata (Wood). Shell dark brown; girdle black, shining and leathery; length up to 75 mm.; breadth 40 mm.: Alaska to Catalina Island, from low-water line to 20 fathoms; eaten by the Indians.

2. Amicula Gray. Shell with the valves externally scarcely visible, the exposed part being heart-shaped and as broad as long; hinder valve with a median sinus and a slit on each side: 3 species.

A. vestita (Sowerby) (*A. emersoni* Couthouy) (Fig. 752). Length 50 mm.; breadth 35 mm.; color of shell light drab; girdle brown, thin, and smooth, showing the valves through it; adults with scattered tufts of hair: New England coast north of Cape Cod in 5 to 30 fathoms.

Fig. 752 *Amicula vestita* (Gould).

3. Cryptochiton Middendorff. Valves concealed by the leathery girdle and lacking tegmenta, their hinder margins produced backwards in a deep lobe on each side, the lobes fusing across the median line: 1 species.

C. stelleri (Midd.). Body oblong, brick red in color; covered with minute spines; length 20 cm.: Pacific coast, south to Monterey, California, just below low tide; eaten by the Indians.

Suborder 3. TELEOPLACOPHORA.

Shell of large size; the anterior valve similar to the posterior, and similarly articulated; insertion plates on all the valves, finely pectinated or grooved, blunt-edged and slit, the teeth all projecting outwards: 10 genera and about 80 species, principally in the Pacific.

Chiton L. Girdle covered with imbricating scales; no eyes present; gills extending the entire length of the foot: 36 species, principally in the West Indies and the Pacific.

C. tuberculatus L. Shell green or olive brown in color, generally spotted; lateral areas with 5 radiating ridges; central areas with longi-

tudinal ridges; up to 9 cm. long and 55 mm. wide: West Indies, Bermuda, Florida, Texas; the commonest West Indian *Chiton.*

C. squamosus L. (Fig. 745). Shell greenish in color and with median keel; central areas of shell longitudinally, lateral areas transversely striated; length 8 cm.: Bermuda and West Indies; Europe.

Class 2. SCAPHOPODA.*

Bilaterally symmetrical, elongated mollusks enclosed in a tapering cylindrical shell, which is open at the two ends and slightly arched, the concave side representing the upper or dorsal side of the body (Fig. 753).

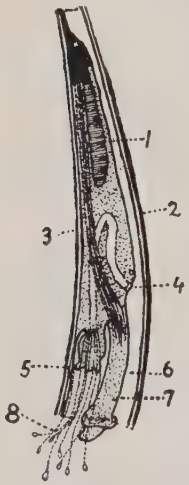

Fig. 753 — Diagram of Dentalium (Lang). 1, gonad; 2, shell; 3, retractor muscle; 4, anus; 5, mouth; 6, mantle cavity; 7, foot; 8, cephalic tentacles.

The mantle folds arise in the larva from the dorsal surface of the very much elongated visceral mass and fuse together ventrally, forming a cylinder open at both ends. From the anterior and larger opening projects the cylindrical foot (7) and a number of slender tentacles (8). The mantle cavity is posterior in position. The head is not developed, the mouth being situated at the extremity of a cylindrical snout (5), where it is usually surrounded by small leaf-like tentacles, while from the base of the snout extend the long slender tentacles above mentioned. No ctenidia are present, the tentacles being possibly homologous to them.

The mouth opens into a V-shaped intestine, in the anterior portion of which is a jaw and a radula; the anus is in the mantle cavity at the base of the foot. The heart is rudimentary, no auricles being present. The nervous system is well developed, paired cerebral, visceral, pedal, pleural, and buccal ganglia being present. No organs of special sense except lithocysts are found. A pair of nephridia opens to the outside by two pores near the anus. The sexes are separate, the single gonad discharging its products through the right nephridium.

History.—The older authors called the scaphopods *Tubulus marinus* or *Denticulus elephantis,* and placed them among the tubicolous annelids with *Serpula,* or among the snails, in the neighborhood of *Patella* or of *Vermetus.* In 1857 Lacaze-Duthiers placed the group under the *Acephala,* maintaining that the twofold origin of the mantle showed a nearer relationship to bivalves than to snails. M. Sars and Bronn, however,

* See "Scaphopoda," by H. Simroth, Bronn's Klassen u. Ord. d. Thier, Vol. 3, 1 Abt., 356, 1894. "Scaphopoda," by H. A. Pilsbry and B. Sharp, Man. of Conch., Vol. 17, 1897.

retained them among the snails, largely because of the radula and jaw, and in 1862 the latter author introduced the name *Scaphopoda,* but for a long time the opinion prevailed that the true position of the group was between snails and bivalves, and that they represented the common ancestors of both. At present the latter view is not generally held, and the systematic position of the *Scaphopoda* is still in dispute. There can be do doubt, however, that they are very primitive mollusks and so aberrant in structure that they should be placed in a Class by themselves.

The *Scaphopoda* are all marine animals, living in clean sand in various depths from shallow water to 2,600 fathoms; they are found in all seas except the polar. About 200 species are known, grouped in two families; about 350 fossil species are known.

Key to the families of *Scaphopoda:*

a_1 Foot trilobate.....1. DENTALIIDAE
a_2 Foot elongate, vermiform.....2. SIPHONODENTALIIDAE

FAMILY 1. DENTALIIDAE.

Foot with 2 lateral epipodial lobes, making it trilobate; oral palps present; lateral teeth of the radula dentate; width of the median tooth of radula double its height: 6 genera and 50 species, most of which are found in deep water.

DENTALIUM L. With the characters of the family: 9 subgenera and numerous species.

D. entale L. (Fig. 754). Shell not much curved, glossy and ivory-like, annulated, without longitudinal striations except at the smaller end; 50 mm. long; 5 mm. wide: Cape Cod to the Arctic Ocean, in 3 to 1,750 fathoms; common; Europe.

Fig. 754
Dentalium entale (Kingsley).

D. pretiosum Sowerby. Like the above, but larger, slenderer, and whiter; length up to 55 mm.; diameter 5 mm.: Pacific coast from Sitka to Lower California.

D. occidentale Stimpson (*D. dentale* Gould). Shell curved like an elephant's tusk, glossy, yellowish-white, with about 20 longitudinal striations, and about 25 mm. long and 8 mm. in diameter: New England coast north of Cape Cod, in from 8 fathoms to deep water.

FAMILY 2. SIPHONODENTALIIDAE.

Foot vermiform, capable of expansion into a terminal disc; width of median tooth much less than double its length: 5 genera and about 60 species, most of which are found in deep water.

Siphonodentalium Sars. Smaller orifice of shell with 2 slight notches on each side.

S. lobatum Sowerby. Shell smooth, shining, thin; 10 mm. long: Arctic seas, south to New England; Europe.

Class 3. GASTROPODA.*

Snails. Asymmetrical mollusks with usually a spirally coiled shell, a distinct head, and a broad, flat foot (Fig. 740, B).

External Structure.—The shell is a spiral cone (Fig. 772), the apex of which represents the dorsal side of the animal. In most snails the spiral twists to the right, and when the apex is uppermost the opening or aperture of the shell will be on the right. In some, however, the twist is normally to the left, and in the right-handed species occasional individuals are found which are left handed. The axis of the shell, around which whorls are coiled is called the columella. When this axis contains a cavity the space is called the umbilicus: sometimes it is partially filled by a thickening called the callus. In certain species, as the slugs, the shell is rudimentary or wanting, and in a few forms, as the limpet, is conical without forming a spiral. In most prosobranchs and some opisthobranchs the aperture of the shell is closed when the animal is withdrawn within it by a disc called the operculum.

The head (Fig. 771) bears one or two pairs of tentacles and a pair of eyes; at its forward end is the mouth, which, in many species, is contained in a long proboscis. The foot represents the ventral side of the body, and is large and has usually a broad sole fitted for creeping on flat surfaces. In the pelagic heteropods and pteropods it is modified to form the fins, and in certain species it is wanting. The foot may secrete a great amount of slime, either from its entire surfaces or from localized glands, which facilitates locomotion.

The visceral mass makes up the greater part of the spiral body, and is covered by the mantle, which extends from the apex to the foot in a single conical fold. The lower edge of the mantle is called the collar (Fig. 771, 7); it can, in many prosobranchs be prolonged to form a siphon. The shell is secreted by the mantle, and follows its spiral windings. The mantle unites with the visceral mass on all sides but one, where a space called the mantle cavity is left between them. In certain primitive snails this is posterior in position, but in the majority of them it has shifted to the right or to the anterior side (Fig. 740, 3). In the mantle cavity are the gills or lungs, and in most snails the external open-

* See "The Mollusca of the Chicago Area: The Gastropoda," by Frank Baker, Natural History Survey, Bull. III, Part II, 1902.

ings of the digestive, excretory, and genital organs. In some snails, especially among the nudibranchs, the mantle is wanting; the shell is also absent in these animals, and the gills, when present, are not homologous to the ctenidia of other mollusks, but are simple outgrowths of the integument of the back.

Internal Structure.—The spiral twisting of the visceral mass of most snails has caused a displacement of the internal organs and the loss of the left-hand member of the primitively paired ones. Thus, but a single ctenidium, kidney, auricle, and osphradium are usually present, instead of a pair. The mouth opens into the pharynx (Fig. 742), which contains the tongue and the radula. In the roof of the pharynx and opposed to the tongue are one or more cuticular plates called the jaws, against which the radula is rubbed in the process of rasping. A pair of salivary glands pour their secretion into the pharynx. The alimentary tract, which consists of the œsophagus, the stomach, and the intestine, bends on itself, the anus being not far from the mouth of the shell.

Three classes of respiratory organs are found—ctenidia, lungs, and adaptive gills. In most cases ctenidia (Fig. 821) are present; pulmonates, both aquatic and terrestrial, breathe by means of lungs; nudibranchs have neither ctenidia nor lungs, but in their place adaptive gills (Fig. 765), which are projections of the dorsal body wall. A few nudibranchs do not possess these organs, but respire through the ciliated integument. The heart bears a close relation to the gills. Certain primitive snails, which possess a pair of ctenidia, have also two auricles, while the majority of them, having but a single ctenidium, have also but one auricle. Nudibranchs and pulmonates have also but one auricle. In the opisthobranchs and the pulmonates the gills or lungs are behind, while in the prosobranchs, as the name indicates, they are in front of the heart.

The excretory organs consist of a single kidney, which opens into the mantle cavity near the anus; it also has a communication with the pericardial (cœlomic) cavity. Those snails which have two ctenidia have also a pair of kidneys.

The nervous system contains the characteristic ganglia. The cerebral ganglia are above and the pedal ganglia below the œsophagus and united by commissures. The pleural ganglia are usually between and joined with these two. The visceral ganglia lie below the intestine and are joined with the pleural, and the parietal are near the visceral. In the prosobranchs and in *Acteon,* an opisthobranch, and *Chilina,* a pulmonate, the commissures joining the visceral with the pleural ganglia cross each other in such a way that the nerve from the right pleural passes over the intestine to the left side of the visceral. Those gastropods in which this occurs are called streptoneurous; the others are called euthy-

neurous or orthoneurous. The sensory organs are a pair of eyes, one or two pairs of tentacles, a pair of lithocysts in the foot, one or two osphradia close to the ctenidia, and the rhinophores of the opisthobranchs, the last two organs being olfactory in function. The osphradia are absent in most snails, which lack ctenidia, but not in all. The rhinophores are the posterior pair of tentacles of the opisthobranchs.

The single gonad empties its products in certain prosobranchs (Patella) through the kidney, but in most gastropods through special genital ducts, to the outside, the genital pore being in the mantle cavity in prosobranchs and outside of it in opisthobranchs and pulmonates. Most prosobranchs are unisexual, while the pulmonates and opisthobranchs are hermaphroditic. The majority of snails are oviparous, and many of them lay their eggs in protective capsules or a jelly; a few are viviparous. Most marine snails leave the egg in the form of the veliger larva; land snails lay eggs, which are covered with a shell, in holes in the ground or similar places, and are born with the form of the parent.

Distribution and Habits.—Most gastropods are aquatic animals, and those which are terrestrial usually require a moist environment. A few are parasitic, either on the outer surface (*Stilifer*) of star-fishes and other animals or as internal parasites (*Entoconcha*) in holothurians. Many are of use to man, *Helix pomatia,* the imported, so-called French snail of the New York markets, and many others, being used for food. The shells also serve often for ornaments and are manufactured into buttons and other articles. In Africa and other countries immense quantities of cowries (*Cypræa moneta*), and several other shells, are used as money.

History.—The class *Gastropoda* was created by Cuvier in 1795, who included under it, among others, the orders *Nudibranchiata, Tectibranchiata,* and *Pulmonata.* The *Pteropoda* he created later, but as a separate class equivalent to the *Gastropoda.* Lamarck in 1812 created the *Heteropoda,* and gave the group equal rank with the *Gastropoda.* Milne-Edwards in 1846-1848 created the orders *Opisthobranchiata* and *Prosobranchiata.* The *Pteropoda* were believed by Leuckart to be the ancestors of the *Cephalopoda,* the arms of which he supposed to have come from pteropod fins, and Lankester has classified them under the *Cephalopoda.* They were, however, universally placed in a class by themselves until Pelseneer, in 1888, showed their affinities to the *Opisthobranchiata.* The same author has also utilized the condition of the pleurovisceral connectives in classification, dividing the *Gastropoda* into two groups, the *Euthyneura,* with the *Opisthobranchiata* and *Pulmonata,* and the *Streptoneura,* with the *Prosobranchiata,* a proceeding which has been adopted in some text-books. The class contains 49,000 species, grouped in 3 orders.

Key to the orders of *Gastropoda:*

a_1 Land and fresh-water snails; lungs, and not gills, present; no operculum.....2. PULMONATA
a_2 Mostly aquatic snails with either ctenidia or adaptive gills.
b_1 Ctenidia posterior in position or adaptive gills present; shells small or wanting; all marine.....1. OPISTHOBRANCHIATA
b_2 Ctenidia at forward end of body; shell well developed; operculum usually present; mostly marine.....3. PROSOBRANCHIATA

ORDER 1. OPISTHOBRANCHIATA.*

Sea slugs. Marine snails, in which the mantle and shell are either entirely wanting, or when present are usually small. The body is asymmetrical, the kidney and genital pores and usually the anus being on the right side; in certain nudibranchs the anus is (secondarily) median and posterior in position. The shell, when present, is usually a spiral. In the nudibranchs the ctenidia and osphradia are absent, respiration being effected either by the general surface of the body or by so-called adaptive gills, which are projections of the dorsal body wall (Fig. 765). The foot has usually a broad sole, but in the pteropods is highly modified, the epipodia alone being well developed, forming a pair of fins, by means of which the animal swims (Fig. 759). In many others also the epipodia form extensive folds which cover the back or are used in many cases in swimming (Fig. 769).

The nervous system is compact, the ganglia being usually near together just behind the pharynx; the pleurovisceral connectives are not crossed except in *Acteon.* Two pairs of tentacles are present, the anterior pair being sometimes absent, the posterior pair (rhinophores) having often a lamellar structure. The eyes are at the base of these posterior tentacles. The radula contains numerous teeth, and the jaw is composed usually of two pieces. The animals are hermaphroditic, the common gonad being protandric; in the lower opisthobranchs it is joined with the genital pore by a single duct, but in the higher ones a distinct oviduct and vas deferens are present. The auricle lies back of the ventricle and receives blood from the gills, which are also mostly posterior in position.

The opisthobranchs are mostly littoral animals living under stones or among seaweed, and feeding principally on animal food, and many are brightly colored. The pteropods as well as representatives of several other groups are pelagic. The order contains over 2,300 species, grouped in 2 suborders.

Key to the suborders of *Opisthobranchiata:*

a_1 Shell usually present; gill in the mantle cavity.....1. TECTIBRANCHIATA
a_2 Shell and mantle absent; adaptive gills on the back.....2. NUDIBRANCHIATA

* See "Manual of Conchology," Vol. 15 and 16, by H. A. Pilsbry, 1893-1896.

Suborder 1. TECTIBRANCHIATA.

Shell and mantle usually present; ctenidium usually present and on the right side (Fig. 760, 1): about 1,400 species, grouped in 3 divisions and 25 families.

Key to the divisions of *Tectibranchiata* here described:

a_1 With well-developed shell, sometimes internal.....1. Bulloidea
a_2 Shell reduced or absent.....2. Aplysioidea

Division 1. BULLOIDEA.

Shell either external or internal and well developed; head with a broad dorsal disc, under which the tentacles, when present, are concealed; epipodia usually present: 15 families.

Key to the families of *Bulloidea* here described:

a_1 Animals not pelagic; no swimming fins.
b_1 Shell external, with a prominent spire.....1. Acteonidae
b_2 Spire very low or sunken.
c_1 Shell external.
d_1 Radula absent.....2. Tornatinidae
d_2 Radula present.
e_1 Cephalic disc not bifurcate.....3. Scaphandridae
e_2 Cephalic disc bifurcate.....4. Akeridae
c_2 Shell internal.....5. Philinidae
a_2 Animals pelagic, with large swimming fins (pteropods).
b_1 Shell spiral, sinistral.....6. Limacinidae
b_2 Shell symmetrical and not spiral.....7. Cavoliniidae

Family 1. ACTEONIDAE.

Shell external, with a prominent spire; epipodia absent, cephalic disc divided behind; operculum horny; pleurovisceral nerve connectives streptoneurous: 7 genera, mostly in warmer seas.

Fig. 755 *Acteon punctostriatus* (Verrill).

Acteon Montfort. Shell solid, ovate; aperture narrow and one-half the length of the shell: 35 species.

A. punctostriatus (Adams) (Fig. 755). Shell conical, with 2 or 3 color bands; aperture long and narrow; inner lip with a strong tortuous fold; animal white; length 6 mm.: Cape Cod to Florida, in 2 to 60 fathoms.

Family 2. TORNATINIDAE.

Small external, more or less cylindrical, with the spire sunken or short and elevated; head triangular or quadrangular; tentacles broad, united at the base; eyes distinct; radula and epipodia absent: 3 genera and 120 species.

1. **Retusa** Brown. Shell with a slightly raised or flat spire; aperture nearly as long as shell, narrow above and dilated below: 50 species.

R. gouldi (Couthouy) (Fig. 756). Shell white and shining, with a yellow periostracum; spire conical; 7.5 mm. long; 2.5 mm. wide: Maine to Cape Hatteras.

2. **Tornatina** Adams. Shell with an elevated apex; inner lip with fold; suture channeled: 50 species.

T. canaliculata (Say). Shell with a low spire, polished, with a channeled suture, white without spots; length 5 mm.; width 2.5 mm.: Atlantic coast south of Cape Cod, in shallow water.

Fig. 756
Retusa gouldi (Dall).

Family 3. SCAPHANDRIDAE.

Shell external, ovate, spire sunken; aperture narrowed above; inner lip spirally convoluted; outer lip acute; head broad and short; epipodia usually well developed; head quadrangular, with eyes at base of tentacular lobes: 6 genera.

1. **Diaphana** Brown. Shell thin and transparent; both inner and outer lips sinuous; epipodia wanting: species few.

D. debilis (Gould). Shell small, greenish-white, with 4 whorls, all rising to the same height, partially umbilicated; 3.5 mm. long; 2.5 mm. wide: Atlantic coast south to New Jersey, in 6 to 50 fathoms; Europe.

2. **Cylichnella** Gabb. Tentacle lobes united and indistinct, with eyes on their front base; shell solid, without spire: 40 species, mostly in deep water.

C. oryza (Totten) (Fig. 757). Shell white, ovate; length 7 mm.; width 2.5 mm.: Maine to Connecticut.

Fig. 757

Fig. 758

Fig. 757—*Cylichnella oryza* (Verrill).
Fig. 758—*Haminea solitaria* (Dall).

Family 4. AKERIDAE.

Shell external, fragile, light-colored, usually covered by the large epipodia, cylindrical or ovate, with a very small sunken spire and a large aperture with a sharp outer lip: 5 genera and 70 species.

Haminea Leach. Shell unicolored, green, or yellow, thin and horny.

H. solitaria (Say) (Fig. 758). Shell ovate, 9 mm. long and 6 mm. wide, shining, with deep, microscopic, impressed lines: common along the Atlantic coast from Massachusetts Bay to South Carolina.

Family 5. PHILINIDAE.

Shell internal, sometimes absent, convex, with a large aperture; epipodia large and fleshy, folded over the back; head without tentacular processes: 4 genera.

Philine Ascanias. Shell with a rudimentary spire, white, translucent, oval; animals slug-like; radula with no central teeth; foot about two-thirds the length of the body and obliquely truncated: 20 species.

P. quadrata (Wood). Shell 5 mm. long, 3.5 mm. wide, with 2 to 3 whorls, squarely globose: New England north of Cape Cod, in rather deep water; Europe.

P. lima (Brown). Shell with 3 to 4 whorls, elongate, broadest anteriorly, 3.5 mm. long, 2 mm. wide, reddish in color: New England north of Cape Cod; Europe.

Family 6. LIMACINIDAE. (Pteropoda Thecosomata.)

Shell and mantle present; shell snail-like, minute, with a left-handed spiral and an operculum; ctenidium and eyes absent; 1 pair of tentacles; mantle cavity, with anus and other openings on right side; 2 large fins present, these being the epipodia, which have extended around the dorsal side of the head: 2 genera and about 19 species, which are pelagic, principally in the northern seas.

Fig. 759

Fig. 760

Fig. 761

Fig. 759—*Limacina arctica* (Leunis). Fig. 760—*Carolinia trispinosa* (Dall). 1, gill, Fig. 761—*Creseis conica* (Dall).

Limacina Cuvier. Shell transparent, with a low spiral and a wide umbilicus: several species in the Arctic and Antarctic seas, which form an important food of whales.

L. arctica (Fabricius) (Fig. 759). Whorls of shell 6; spire low; umbilicus wide; width 4 mm.: Arctic seas, south to New Jersey.

Family 7. CAVOLINIIDAE. (Pteropoda Thecosomata.)

Shell and mantle present; shell not spiral, but symmetrical, straight or curved, without operculum; ctenidium and eyes absent; 1 pair of tentacles; mantle cavity ventral; 2 large fins present as in previous family: about 50 species, all of which are pelagic.

1. **Cavolinia** Abildgaard (*Hyalea* Lamarck). Shell globular, with 3 long sharp spines posteriorly; aperture contracted with a slit on each side, through which long appendages of the mantle pass: 10 species.

C. trispinosa (Lesueur) (Fig. 760). Length 10 mm.; median spine as long as the body; lateral spines only a third as long: Atlantic coast.

2. Creseis Rang. Shell conical, slender, pointed, straight or slightly curved: 6 species.

C. conica Eschscholtz (Fig. 761). Length 12 mm.; diameter 2 mm.: Atlantic coast.

Division 2. APLYSIOIDEA.

Shell reduced or absent; head without cephalic disc and with 2 pairs of tentacles; epipodia present, which arise from the sides of the body and not the foot; osphradium present: 6 families, all but the *Aplysiidae* being *Pteropoda Gymnosomata,* or shell-less pteropods.

Key to the families of *Aplysioidea* here described:

a_1 Shell present; animals live on seaweed.....1. Aplysiidae
a_2 Shell absent; animals pelagic (pteropods).....2. Clionidae

Family 1. APLYSIIDAE.

Sea hares. Body large; shell rudimentary and internal; animal slug-like, with the anterior angles of the head extended into 2 large tentacular folds, behind which are a pair of eyes and behind these the rhinophores; epipodia, which are large lobes, turn up over the back: 7 genera and numerous species; cosmopolitan; mostly large, brightly colored slugs, which secrete a reddish fluid from the mantle wrongly supposed by many to be poisonous.

Aplysia L. Animal swollen behind, with a long neck and head; shell flexible; epipodia mobile and used for swimming: 50 species.

A. protea Rang. Length 16 cm.; color variable, yellow or green, with ring-shaped spots of black, red, and green: common in the West Indies, also on the Florida coast.

A. californica Cooper. Length up to 37 cm.; color gray or greenish, purple on the sides, covered with brown lines and blotches; epipodia behind the middle: Monterey to San Pedro.

Fig. 762 *Clione limacina* (Gould).

Family 2. CLIONIDAE. (Pteropoda Gymnosomata.)

Shell and mantle absent; body fusiform; head distinct, with 2 pairs of tentacles, the hinder of which bears eyes; foot represented by a pair of fins which spring from the base of the neck; between the base of the fins the rudiment of the median portion of the foot; gill absent; proboscis generally with suckers or with lateral lobes which bear suckers: 14 genera; pelagic.

Clione Pallas. With the characters of the family: 10 species.

C. limacina (Phipps) (Fig. 762). Body tapering to a point behind, 35 mm. long, pale blue in color and hyaline; fins triangular: Arctic

Ocean, south to New York; it swims about near the surface in immense schools, sometimes coloring the sea for miles, and forms an important source of food of whales.

Suborder 2. NUDIBRANCHIATA.

Sea slugs. Shell, ctenidium, and osphradium absent, but a coiled shell is present in the embryo; respiration either through the integument, no gills being present, or by means of adaptive gills; these surround the anus when it is median and dorsal in position, or form longitudinal or transverse rows; in the latter case they are called cerata and usually contain hollow extensions of the liver and also nematocysts, which, however, are derived from ingested hydroids; 2 pairs of tentacles present: about 1,000 species, grouped in 4 divisions and 19 families.

Key to the divisions of *Nudibranchiata:*

a_1 Cerata usually present; anus lateral.
  b_1 Cerata branched or foliaceous, in 2 rows.....1. Tritonioidea
  b_2 Cerata simple or absent.
    c_1 Jaws present; several rows of cerata on each side.....3. Æolidiodea
    c_2 Jaws absent; cerata usually absent.....4. Elysioidea
a_2 Anus median and posterior, surrounded by a circle of adaptive gills. 2. Doridioidea

Division 1. TRITONIOIDEA.

Two longitudinal rows of branched cerata usually present, into which the liver usually does not extend, and without nematocysts; anus on right side: 7 families.

Key to the families of *Tritonioidea* here described:

a_1 Two pairs of cerata.....1. Scyllæidae
a_2 More than 2 pairs of cerata.....2. Dendronotidae

Family 1. SCYLLÆIDAE.

Body elongate, with a narrow foot; anterior tentacles absent; 2 pairs of branched, foliaceous cerata; male and female openings contiguous: 1 genus.

Scyllæa L. Body narrow and compressed; oral tentacles wanting; rhinophores retractile: 8 species.

S. pelagica L. (*S. edwardsi* Verrill). Cerata spatulate, bearing small tufted projections on the inner surface, similar projections being on the back; foot very narrow; color brownish or orange, irregularly spotted; length 75 mm.; width 12 mm.: pelagic, living on floating seaweed.

Family 2. DENDRONOTIDAE.

Body elongate; tentacles laminated and branched, forming fringed frontal appendages; 2 rows of branched cerata on the back into which the liver extends: 4 genera.

Dendronotus Alder and Hancock. With the characters of the family.

D. arborescens (O. F. Müller) (Fig. 763). Color pale or red with brownish or whitish spots; cerata transparent, 5 to 7 on a side; length 8 cm.: on rocks and seaweed; circumpolar, south to Rhode Island; common in Casco Bay; Europe.

Fig. 763—*Dendronotus arborescens* (Gould).

Division 2. DORIDIOIDEA.

Anus median and posterior and surrounded by a circle of adaptive gills into which the liver does not extend: 5 families.

Key to the families of *Doridioidea* here described:

a_1 Mantle with lateral tubercles or appendages.....1. Polyceridae
a_2 No lateral tubercles or appendages.....2. Doridae

Family 1. POLYCERIDAE.

Body elongate, with a marginal ridge on each side bearing tubercles or appendages; integument with spicules; rhinophores not retractile and usually lamellate; gills non-retractile and with lateral projections: about 8 genera.

Key to the genera of *Polyceridae* here described:

a_1 Marginal ridge with short tubercles of nearly equal length.....1. Polycera
a_2 Marginal ridge with long appendages, some at base of rhinophores. 2. Ancula

1. Polycera Cuvier. Body limaciform; mantle indistinct, forming a projecting frontal velum and a tuberculated ridge along each side: 11 species.

P. lessoni D'Orbigny. Length 30 mm.; color greenish; about 6 long, finger-like tubercles on a side, tipped with yellow; a median row of tubercles also present; head with 6 projecting points on each side: Long Island Sound and northwards; Europe; common in Casco Bay from low water to 20 fathoms.

Fig. 764—*Ancula sulphurea* (Gould).

2. Ancula Lovén. Body limaciform and smooth; head bearing tentacular projections at the base of the rhinophores as well as one at side in front, and also several surrounding the gills: 3 species.

A. sulphurea Stimpson (Fig. 764). Body slender, 30 mm. long, light brownish and transparent; rhinophores club-shaped; 3 branched,

pinnate gills, surrounded by 8 to 12 long projections; all tentacles and projections tipped with yellow: New England north of Cape Cod, often common under stones.

Family 2. DORIDIDAE.

Mantle large, covering the head and without marginal appendages; integument generally very spiculose; rhinophores laminate and retractile; anterior tentacles small; gills usually retractile: 9 genera.

Key to the genera of *Doridida*e here described:

a_1 Gills retractile.....1. Doris
a_2 Gills not retractile.
b_1 Gills pinnate and simple.....2. Onchidoris
b_2 Gills bipinnate.....3. Acanthodoris

1. Doris L. Body depressed, often with dorsal tubercles; gills branched or feathered, united at the base, and retractile; mouth with 2 oral lobes: 150 species; cosmopolitan.

Fig. 765
Doris bifida (Verrill).

D. repanda Alder and Hancock. Body broad, light-colored, covered with minute white tubercles; mantle expanded beyond the foot; gills form a star of about 10 pinnate plumes; length 15 mm.; width 12 mm.: New England north of Cape Cod, under stones at low-water line; Europe.

D. bifida Verrill (Fig. 765). Body broad and oval, purplish-brown in color, speckled with white, 25 mm. long, 12 mm. wide; back very convex, with papillae; gills with 7 bipinnate plumes: New England from Long Island Sound to Eastport, under stones at low-water mark.

2. Onchidoris Blainville. Body depressed; head with a veil in place of oral tentacles; gills pinnate, set in a circle and non-retractile: 23 species.

O. bilamellata (L.). Body elliptical, brownish or pink in color, covered with short, unequal papillae; gills 20 to 25 in number, slender and arranged in an oval; length 25 mm.; width 12 mm.: Atlantic coast, north of Cape Cod; often common; Europe.

O. pallida (Agassiz). Body elongate, cream-colored, covered with large mushroom-like tubercles; gills form a star of 7 or 8 broad plumes, which are retractile; 12 mm. long, 6 mm. wide: Cape Cod northwards, from low-water mark to 30 fathoms; Europe.

3. Acanthodoris Gray. Body convex, covered with soft papillae; oral lobes united to form a veil; gills united at the base and non-retractile: 4 species.

A. stellata Verrill. Body broad, narrower behind, covered with small pointed papillae; gills composed of 7 bipinnate plumes; color

variable, often purplish; length 25 mm.; width 12 mm.: Long Island Sound and northwards, under stones at low-water mark.

Division 3. ÆOLIDIOIDEA.

Simple unbranched cerata on each side, into which liver projections extend and which often contain nematocysts; anus usually on right side: 9 families.

Key to the families of *Æolidioidea* here described:

a_1 Numerous cerata, in transverse rows.....1. Æolididae
a_2 One longitudinal row of cerata on a side.....2. Dotonidae

Family 1. ÆOLIDIDAE.

Cerata arranged in transverse rows along the body, which contain nematocysts, which, however, have been introduced with the hydroids on which the animals feed; no spicules in integument and no mantle; tentacles non-retractile; anus on the right side: 100 species, the animals feeding largely on hydroids and bryozoans.

Key to the genera of *Æolididae* here described:

a_1 Body broad, being at least a third as broad as long.....1. Æolis
a_2 Body usually less than a quarter as broad as long.
b_1 The 2 pairs of tentacles unequal in length.
c_1 Front angles of foot not prolonged.....2. Æolidia
c_2 Front angles of foot prolonged.....4. Coryphella
b_2 The 2 pairs of tentacles of equal length.....3. Flabellina

1. Æolis Cuvier. Body ovate; cerata cylindrical and numerous, extending along the entire back; 2 pairs of cylindrical tentacles: numerous species.

A. papillosa (L.) (Fig. 766). Body broad, depressed, tapering behind, gray or orange-colored, spotted with brown or white; cerata crowded, arranged in 12 to 20 imbricated oblique rows on each side and 10 or 12 in a row; length 7 cm.; width one-third the length: Rhode Island to Arctic Ocean, among hydroids and under stones between tide lines; Europe.

Fig. 766
Æolis papillosa (Gould).

2. Æolidia Cuvier. Tentacles of unequal length; cerata compressed, in transverse, rather distant rows: 4 species.

A. pilata (Gould). Body elongate, 38 mm. long, 6 mm. wide, pale drab in color with a mid-dorsal, interrupted carmine stripe margined with silvery dots; cerata fusiform, in 5 groups: Long Island Sound to Massachusetts Bay.

A. diversa (Couthouy). Body elongate, tapering to a point, pale yellow in color; oral tentacles long and slender; dorsal tentacles shorter;

cerata fusiform with an orange-colored interior, arranged in transverse groups of 3 or 4; length 30 mm.; width 8 mm.: Cape Cod, northwards.

3. **Flabellina** Cuvier. Body slender; rhinophores laminated; oral tentacles elongate; cerata on compressed stalks: several species.

F. bostoniensis (Couthouy). Body drab in color with a silvery line on the tail and the back of the oral tentacles; cerata curve backwards, arranged in 5 or more groups on each side, white-tipped; length 25 mm.; width 7 mm.: Cape Cod and northwards.

4. **Coryphella** Gray. Front angles of foot elongated to form long lobes: 18 species.

C. gymnota (Couthouy). Body slender and tapering to a point, white in color; oral tentacles longer than the dorsal, which have wrinkled sides; cerata arranged in 6 to 10 transverse clusters, with a vermillion interior and white tips; length 25 mm.; width 3 mm.: Woods Hole to Boston.

C. mananensis (Stimpson). Body white in color; cerata vermillion with white tips; rhinophores brown and wrinkled; length 35 mm.: Cape Cod and northwards.

Family 2. DOTONIDAE.

Cerata tuberculated and in a single row on each side, numerous, without nematocysts; tentacles retractile; foot very narrow; a simple veil in front: 4 genera.

Doto Oken. With the characters of the family: 4 species.

D. coronata (Gmelin) (Fig. 767). Body slender; brown or pink in color, but variable; 12 mm. long; cerata large, club-shaped, 5 to 8 on a side, with red spots: New Jersey to Labrador in shallow water, on *Bryozoa* and hydroids; often common.

Fig. 767
Doto coronata (Verrill). A, dorsal aspect; B, one of the cerata.

Division 4. ELYSIOIDEA.

Cerata either present, when they receive extensions of the liver, or absent; jaws absent; radula with but one row of teeth: 3 families.

Key to the families of *Elysioidea:*

a_1 Cerata present.....1. Hermæidae
a_2 Cerata absent.
b_1 Two lateral ridges present.....2. Elysiidae
b_2 Ridges absent.....3. Limapontiidae

Family 1. HERMÆIDAE.

Cerata present; 1 pair of tentacles, non-retractile or absent; anus dorsal and median: 4 genera.

1. **Alderia** Allman. Body elongate, without tentacles; head with lobes at the side; anus dorsal, posterior: 4 species.

A. harvardiensis (Agassiz) (Fig. 768). Body square and broad in front, tapering behind; cerata short, arranged in 6 or 7 clusters on each side with 2 in each cluster; color brownish-yellow; length 12 mm.; width 4 mm.: in shallow pools, north of Cape Cod; often common.

2. **Tergipes** Cuvier. Foot rudimentary; cerata in a single row on each side; tentacles cylindrical: several species.

T. despectus Johnston. Four club-shaped cerata on each side; dorsal tentacles long, oral tentacles short: Long Island Sound northwards; often abundant on hydroids in shallow water.

Family 2. ELYSIIDAE.

Body without cerata, but ciliated, and with 2 lateral ridges, containing hepatic cæca; radula with a single series of strong teeth; eyes on the sides of the head; anus median or latero-dorsal: 15 species.

Fig. 768

Fig. 769

Fig. 770

Fig. 768—*Alderia harvardiensis* (Gould). Fig. 769—*Elysia chlorotica* (Gould). Fig. 770—*Elysia catula* (Gould).

1. **Elysia** Risso. Body elliptical, depressed; wing-like ridges wide; 2 rather short, thick tentacles: 7 species.

E. chlorotica (Agassiz) (Fig. 769). Body slender, bright green in color, dotted with white and red spots, 40 mm. long, 8 mm. wide; ridges broad, folding over the back, overlapping when the animal crawls, and expanded, leaf-like, when it swims: New Jersey to Boston, in shallow and brackish water; often abundant.

E. catula (Ag.) (Fig. 770). Body elongate, brownish-green in color, with a few whitish spots, 6 mm. long and 2 mm. wide; ridges when folded do not overlap: New Jersey to Boston; common among eel grass and shallow water.

Family 3. LIMAPONTIIDAE.

Body minute without lateral expansions or cerata; sides of head with ridges; anus median and posterior: 6 species.

Limapontia Johnston. Eyes on the lateral cephalic crests: several species.

L. zonata (Girard). Body reddish in color with transverse white bands: Massachusetts.

Order 2. PULMONATA.*

Fresh-water and land snails (Fig. 771). Small snails, in most of which the shell is a simple, regular spiral. The aperture of the shell (Fig. 772) is more or less circular or crescentic and usually rather small, and is sometimes contracted by the presence of teeth or lamellae (7). It has an outer lip or peristome (4) which is either acute or expanded, and an inner or parietal lip (towards the axis of the shell) which may be either thickened or not. *Arion* and *Limax* have no outer shell, but rudiments of one are embedded in the wall of the mantle, while *Philomycus* is altogether shell-less. An operculum is not found, but many land snails close the aperture, on beginning their hibernation, by means of a partition of cal-

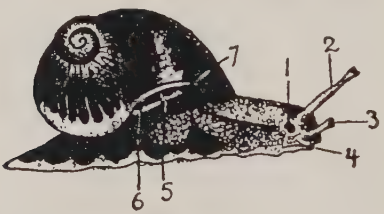

Fig. 771

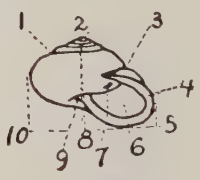

Fig. 772

Fig. 771—*Helix aspersa* (Lang). 1, genital pore; 2, posterior tentacle, with an eye at its tip; 3, anterior tentacle; 4, pedal gland; 5, respiratory pore; 6, anus; 7, collar. Fig. 772—Diagram of a pulmonate shell (Walker). 1, suture; 2, apex; 2–8, height or length of shell; 3, spire; 4, lip; 5–10, width of shell; 6, aperture; 7, parietal tooth; 9, umbilicus.

cified slime called the epiphragm. The mantle cavity has an anterior position, except in the *Onchidiidae,* the opening to the outside being a small pore on the right side of the body (Fig. 771, 5), which can be closed at will in order to keep out the water in the aquatic species and prevent desiccation in the terrestrial ones. Ctenidia are not present and aerial respiration is carried on by the vascular inner lining of the mantle cavity. The aquatic species are no exception to this rule, but must in most cases come to the surface of the water to obtain atmospheric air; young individuals, however, and the adults of a few species which live in the depths of deep lakes, take water into the mantle cavity, and thus respire.

The head bears either one or two pairs of tentacles. In the aquatic pulmonates but one pair is present (Fig. 776), which are not hollow or retractile and have a pair of eyes at their base; while the land pulmonates have two pairs of tentacles (Fig. 771), at the tips of the posterior and larger pair of which are the eyes. The jaw is composed of either

* See "Land and Fresh-Water Shells of North America," Parts 1 and 2, by W. G. Binney, Smithsonian Misc. Coll., No. 143 and 194, 1865. "Manual Am. Land Shells," by same, Bull. 28, U. S. Nat. Mus., 1885.

a single or of several pieces, but never of two symmetrical pieces; the radula is broad, often nearly as broad as long, with many transverse rows of very numerous teeth. These rows are either straight, curved, or angulated. The pulmonate tooth has a broad base and a recurved and either spine-like or dentate crown.

The pulmonates are hermaphroditic animals, a single protandric gonad, the hermaphroditic gland, being present. The aquatic forms have two genital pores, while most land pulmonates have but one. The genital tract is considerably more complex in some forms than in others. A few snails bear living young, but most of them lay eggs, those of the land forms having calcareous shells and being deposited in the ground and other moist places, while those of the aquatic forms are surrounded by a transparent jelly.

The majority of the *Pulmonata* live on the land, either on the ground among decaying leaves, in rotting wood, or in other dark moist places, or sometimes among the foliage of trees and shrubs. The aquatic forms are found on vegetation or on muddy or sandy banks in streams and fresh-water ponds and lakes; a few are marine. A few pulmonates are carnivorous, feeding on other snails and other small animals, but the great majority live on vegetable substances. About 19,000 species of pulmonates are known, which are grouped in two suborders.

Key to the suborders of *Pulmonata:*

a_1 Aquatic pulmonates; but 1 pair of tentacles.....1. Basommatophora
a_2 Land pulmonates; 2 pairs of tentacles.....2. Stylommatophora

Suborder 1. BASOMMATOPHORA.

Fresh-water, or in a few cases marine or terrestrial, snails with but 1 pair of tentacles (Fig. 776), which are solid and usually flattened, and at the base of which are a pair of eyes; shell delicate, usually with a conical spire and a large aperture; 2 genital pores, usually on the right side of the body, the male opening near the tentacle, the female opening a little farther back, near the respiratory opening; ureter passes directly forward from the kidney (Orthurethra): cosmopolitan, there being about 4,000 species, grouped in 11 families.

Key to the families of *Basommatophora* here described:

a_1 Shell spiral.
  b_1 Inner lip of aperture toothed.....1. Auriculidae
  b_2 Lip smooth.
    c_1 Spire raised.
      d_1 Shell right-handed.....2. Lymnæidae
      d_2 Shell left-handed.....3. Physidae
    c_2 Spire discoid.....4. Planorbidae
a_2 Shell conic, not spiral.....5. Ancylidae

Family 1. AURICULIDAE.

Shell spiral with a horny periostracum; lower whorl usually very large with an elongated aperture which has folds on the parietal wall and usually teeth on the outer lip; head projects snout-like in front of the cylindrical tentacles: several hundred species, which live largely in salt marshes, principally in tropical countries; about 20 American species.

Key to the genera of *Auriculidae* here described:

a_1 Spire of shell at least as long as its aperture.
b_1 Shell not minute.....1. Phytia
b_2 Shell minute.....2. Carychium
a_2 Spire much shorter than the aperture.....3. Melampus

1. Phytia Gray. Shell conical with a pointed spire; aperture with 1 to 5 teeth on the parietal wall; jaw slightly arched, smooth, with a slight median projection; foot with a transverse groove: several species, principally Mediterranean, 1 American.

P. myosotis (Draparnaud) (Fig. 773). Height 8 mm.; diameter 4 mm.; horn-color with a reddish sutural line: marine; Nova Scotia to

Fig. 773

Fig. 774

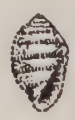

Fig. 775

Fig. 773—*Phytia myosotis* (Verrill). Fig. 774—*Carychium exiguum* (Baker). Fig. 775—*Melampus lineatus*—a banded individual (Verrill).

Chesapeake Bay, also at San Francisco, near high-water mark along the shore, being common in crevices of wharfs; an European species, perhaps imported.

2. Carychium O. F. Müller. Shell very thin and like a *Pupa* in form; aperture oval with 1 or 2 teeth on parietal wall; jaw smooth: about 15 species, principally European; terrestrial.

C. exiguum (Say) (Fig. 774). Height 1.75 mm.; diameter .75 mm.; color of shell white, with 4½ whorls: under and in logs and moss in moist places in eastern and central states; Oregon; common.

3. **Melampus** Montfort. Shell with a very short, blunt spire and a very large lower whorl; aperture long and narrow; inner lip with several transverse folds; outer lip acute: 120 species, mostly tropical; amphibious or found in brackish water; 4 American species.

M. lineatus Say (Fig. 775). Shell 13 mm. long and 7 mm. thick, horn-color or reddish-gray, with 4 or 5 revolving bands when young, aperture with a white callus and a prominent tooth on the parietal wall: among the grass of salt marshes, near high-water line, from New England to Texas; common.

Family 2. LYMNÆIDAE.*

Shell thin, usually with a prominent acute spire and a large, often flaring aperture, varying from horn-colored to black; lip acute and simple; parietal wall of aperture with a white callus which entirely or partially covers the umbilicus; tentacles flattened; eggs laid in a jelly; radula with unicuspid central tooth: several genera with several hundred species, inhabiting ponds, swamps, and streams in all parts of the globe, but principally in temperate regions; about 35 species in the United States.

Lymnæa Lamarck. Jaw composed of 3 pieces, 1 large transversely elongate piece and 2 small ones; foot rounded behind: over 200 species, 65 American.

Key to the species of *Lymnæa* here described:

a_1 Shell more than 25 mm. long.
  b_1 Spire long and slender.....L. STAGNALIS
  b_2 Spire short.
    c_1 Aperture about half the length of the shell.....L. MEGASOMA
    c_2 Aperture almost or quite as long as the shell.....L. AURICULARIA
a_2 Shell less than 20 mm. long.
  b_1 Aperture about half the length of the shell or longer.
    c_1 Shell with 4 whorls.
      d_1 Parietal callus straight.....L. COLUMELLA
      d_2 Parietal callus with a slight fold or angle in the middle...L. CATASCOPIUM
    c_2 Shell with 5 or 6 whorls.
      d_1 Shell 15 mm. long.....L. OBRUSSA
      d_2 Shell 8.5 mm. long.....L. HUMILIS
  b_2 Aperture less than half the length of shell.
    c_1 Shell very long and slender, aperture elongate.....L. REFLEXA
    c_2 Shell not unusually slender.
      d_1 Shell 30 mm. long or less.....L. PALUSTRIS
      d_2 Shell 15 mm. long or less with heavy spiral lines.....L. CAPERATA

L. stagnalis (L.) (Fig. 776). Spire of shell long and slender, with an acute apex; aperture flaring; whorls 6; length 60 mm.; width 25 mm.: circumpolar, being found in the northern states from the Atlantic to the Pacific; often common in ponds; the largest species; Europe.

L. columella Say. Shell extremely thin and fragile, greenish or yellowish in color, with 4 whorls, of which the last is large and forms nearly the whole shell; length 17 mm.; width 6 mm.; aperture ovate: central and eastern states; often common in stagnant and miry pools and streams.

L. megasoma Say. Shell thick, with a short spire; length 40 mm.; thickness 25 mm.: northern states from Vermont to Michigan.

L. reflexa Say (Fig. 777). Shell long and slender, fragile, with 6 to 7 whorls; aperture rather narrow; length 40 mm.; width 13 mm.:

* See "Lymnæidae of North and Middle America," by F. C. Baker, Chicago Acad. Sci., Special Pub. No. 3, 1911.

northern states from New York to the Pacific, also in the middle central and western states; often common.

L. palustris (O. F. Müller) (*L. elodes* Say) (Fig. 778). Shell from pale brown to black in color, elongate, conical, with an acute apex which is sometimes broken off and with rather more than 6 whorls, which are decidedly convex; aperture shorter than the spire with an acute lip and a white callus on the parietal wall; length 30 mm.; width 12 mm.: circumpolar; northern America; the commonest species; Europe.

L. obrussa Say. Like the above, but shell with only 5 whorls and a larger aperture, and very much smaller: New England to Kansas; California; common about the muddy margins of ponds.

Fig. 776

Fig. 777

Fig. 778

Fig. 776—*Lymnæa stagnalis* (Baker). 1, foot; 2, tentacle. Fig. 777—*Lymnæa reflexa* (Baker). Fig. 778—*Lymnæa palustris* (Baker).

L. catascopium Say. Shell broad and robust, usually reddish or blackish with 4 to 5 whorls, the last large and very convex, with a large, flaring aperture; length 17 mm.; width 12 mm.: northern and central states; common in large rivers and lakes.

L. humilis Say. Shell small, thin, and transparent, with 5 or 6 whorls, 8.5 mm. long, regularly conical and somewhat elongate, variable in color, sometimes blackish; distinct umbilicus present: entire eastern and central America, on the muddy banks of streams.

L. auricularia (L.). Shell large, with a very short, acute spire and a very large, ear-shaped aperture, which takes up almost the whole shell; length 33 mm.; width 25 mm.: an European species, introduced locally in many eastern localities.

L. caperata Say. Shell rather solid, yellowish to black in color, with 5 to 6 whorls, with numerous minute revolving lines, 15 mm. long, 7 mm. wide: New England to California and northwards.

Family 3. PHYSIDAE.

Shell sinistral, thin, with an acute spire, a large lower whorl, and a large oval aperture, with an acute lip and a wide callus on the parietal wall; jaw a single piece, foot pointed behind; tentacles filiform: over 150 species; cosmopolitan; about 22 in this country; in swamps and ponds.

Key to the genera of *Physidae* here described:

a_1 Margin of mantle digitate.....1. PHYSA
a_2 Margin of mantle simple.....2. APLEXA

1. PHYSA* Draparnaud. Mantle reflected over a portion of the shell and fringed with finger-like filaments: 100 species.

Key to the species of *Physa* here described:

a_1 Whorls 5 or 6.
  b_1 Aperture three-fourths the length of shell or more.....P. SAYI
  b_2 Aperture two-thirds the length of shell or less.....P. GYRINA
a_2 Whorls about 4.
  b_1 Spire very short.....P. ANCILLARIA
  b_2 Spire acute.....P. HETEROSTROPHA

P. sayi Tappan. Shell with 5 or 5½ whorls, with an elevated, acute spire and with numerous impressed spiral lines; aperture large, three-fourths or four-fifths the length of the shell; length 22 mm.; width 13.5 mm.: northern states, west to Rocky Mountains, south to Ohio River.

Fig. 779

Fig. 780

Fig. 779—*Physa gyrina* (Baker). Fig. 780—*Physa heterostropha* (Baker).

P. gyrina Say (Fig. 779). Shell an elongate cone with 5 or 6 whorls, with numerous impressed spiral lines; aperture more than half but less than two-thirds the length of the shell; length 23 mm.: Mississippi valley, the commonest species in the central states.

P. ancillaria Say. Shell with 4 or 5 whorls, a very short spire, and a very large bulging lower whorl; aperture almost as long as the shell; color pinkish or yellowish; length 14 mm.; suture inconspicuous: eastern and northern states, often common.

P. heterostropha (Say) (Fig. 780). Shell smooth and polished and without spiral lines, with 4 whorls, the first very large, the others very small, with an acute apex; aperture large, elongate, and three-fourths the length of the shell; color yellowish-brown or blackish; length 14 mm.; breadth 8.5 mm.: entire country; the commonest species in the eastern states.

2. APLEXA Fleming. Mantle not reflected over the shell and with a simple edge: several species.

* See "A Revision of the Physae of North Eastern Illinois," by F. C. Baker, Nautilus, Vol. 14, p. 16, 1900. "The American Physae," by O. A. Crandall, Nautilus, Vol. 15, Nos. 3, 4, 5, 6, 1901.

A. hypnorum (L.) (*Physa elongata* Say) (Fig. 781). Shell elongate, with 6 whorls, yellow or brown in color, 17 mm. long and 8 mm. wide; aperture narrow, about half the length of the shell: circumpolar; on muddy bottoms.

Fig. 781
Aplexa hypnorum (Baker).

FAMILY 4. PLANORBIDAE.

Shell sinistral and discoidal, having a flat or depressed spire, in some cases apparently dextral; tentacles filiform; radula with biscuspid central teeth; genital pores on the left side; jaw composed of 3 pieces: 170 species; in streams, ponds, and lakes, on muddy bottoms or on submerged objects or vegetation.

Key to the genera of *Planorbidae* here described:

a_1 Interior of whorls without teeth.....1. PLANORBIS
a_2 Interior of whorls with teeth.....2. SEGMENTINA

1. PLANORBIS L. Shell discoidal and sinistral, the spire being flattened or sunken, with 3 to 5 whorls; umbilicus large and wide; lip simple and acute: over 150 species; cosmopolitan, but found mostly in temperate regions; 26 American species.

Key to the species *Planorbis* here described:

a_1 Shell sinistral and about 12 mm. wide or more.
  b_1 Aperture not flaring.....P. TRIVOLVIS
  b_2 Aperture flaring.
    c_1 Keeled on both sides.....P. BICARINATUS
    c_2 Keel on one side.....P. CAMPANULATUS
a_2 Shell apparently dextral and about 6 mm. wide.
  b_1 Periphery acutely keeled.....P. EXACUTUS
  b_2 Periphery rounded.
    c_1 Aperture deflected upwards.....P. DEFLECTUS
    c_2 Shell hirsute.....P. HIRSUTUS
    c_3 Shell regular and smooth.....P. PARVUS

P. trivolvis Say (Fig. 782). Shell sinistral, yellowish or brown, with 4 whorls; spire sunken; aperture large, with a sharp and simple lip, which has a V-shaped angle above; umbilicus showing almost all of the whorls; height 9 mm.; width 22 mm.: North America; the commonest species.

Fig. 782
Planorbis trivolvis (Baker).
A, upper surface; B, under surface.

P. bicarinatus Say. Shell sinistral, deeply concave on both sides, pale yellow or brown, with 3 whorls, 6 mm. high and 12 mm. broad, keeled on both sides; aperture large: northern and central states; south to Georgia and Kansas; California.

P. campanulatus Say. Shell sinistral, flat, with 4 whorls; aperture flaring and bell-shaped; height 7 mm.; breadth 14 mm.: northern and central states.

P. exacutus Say (Fig. 783). Shell apparently dextral, with an acute periphery, 4 whorls, white or light yellowish in color; 6 mm. wide: northern states, south to Kansas.

P. deflectus Say (Fig. 784). Shell apparently dextral, with a blunt keel at the periphery, and 4 whorls, the largest whorl being deflected from the plane of the others: North America, south to Washington.

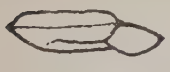

Fig. 783

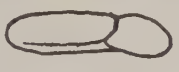

Fig. 784

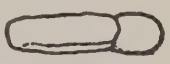

Fig. 785

Fig. 783—*Planorbis exacutus* (Baker). Fig. 784—*Planorbis deflectus* (Baker). Fig. 785—*Planorbis parvus* (Baker).

P. hirsutus Gould. Shell brownish, with 3 whorls; surface beset with revolving lines of delicate hairs; aperture large and very oblique; diameter 5 mm.: circumpolar; south to Washington.

P. parvus Say (Fig. 785). Shell apparently dextral, with a rounded periphery and yellowish to blackish in color, with 4 whorls; 5 mm. in diameter; periphery rounded: North America; very common, especially on water plants.

2. **Segmentina** Fleming. Shell sinistral, discoidal, with a flattened or sunken spire, furnished internally with transverse partitions or teeth; lip simple: but few species, principally in the Old World.

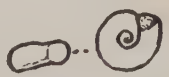

Fig. 786 *Segmentina armigera* (Baker).

S. armigera (Say) (Fig. 786). Shell flat on the upper and concave on the lower side, with 4 whorls; 5 internal teeth present, far within the aperture, which nearly close the passage; diameter 6 mm.; height 2.5 mm.: North America; often abundant; sometimes gregarious.

Family 5. ANCYLIDAE.

Shell thin, non-spiral, conical, with the apex median or directed to the right, and an oval aperture; jaws 3, covered by papillae; tentacles triangular, with eyes at their base: 8 genera and about 60 species; cosmopolitan.

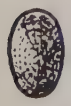

Fig. 787 *Ancylus rivularis* (Baker).

Ancylus Geoffroy. River limpets. With the characters above given: 16 American species.

A. parallelus Haldeman. Shell elongate, with the sides parallel and the ends blunt, with apex nearly in the center, dark green in color; 5 mm. long and half as wide: New England, on stones and leaves in brooks and ponds.

A. rivularis Say (Fig. 787). Shell oval, horny, white within, 6 mm. long; apex obtuse, nearer to and leaning towards one side and one end: eastern states, sometimes common on dead shells and stones.

Suborder 2. STYLOMMATOPHORA.*

Land snails with 2 pairs of retractile tentacles, the hinder and larger pair bearing a pair of eyes at their tips (Fig. 771); shell absent or concealed in the slugs, and in the other forms usually with 4 to 6 whorls which form a more or less conical spire (Fig. 772); respiratory pore on the right side of the body (Fig. 771, 5), with the anal and excretory pores near it; either 2 (Ditremata) genital pores or 1 (Monotremata); in the latter case, which characterizes all the American families except the *Onchidiidae,* the pore is near the base of the right hinder tentacle (Fig. 771,1); ureter passes either directly forward from the kidney towards the anterior margin of the lung (Orthurethra), or is reflexed, passing first to the posterior end of the lung cavity (Sigmurethra): about 20 families, with about 15,000 species. The American forms fall into several distinct groups. These are (1) the indigenous American snails, including almost all those species occurring east of the Sierra Nevada and Cascade mountains; (2) the boreal species, certain small northern forms of circumpolar distribution; (3) the Pacific slope species, which have migrated there from Asia by way of Alaska; (4) the European species, introduced by human agency; and (5) the southern species, which have entered the country from Central America and the West Indies.

Key to the families of *Stylommatophora* here described:

a_1 Shell present.
  b_1 Shell with a high spire, being conical or cylindrical, not heliciform (except *Strobilops*).
    c_1 Shell more or less cylindrical, pupiform (Fig. 788).....2. Pupillidae
    c_2 Shell conical; with an acute apex.
      d_1 Jaw present.
        e_1 Spire very small, composed of 2 or 3 whorls.....5. Succineidae
        e_2 Spire high, composed of 5 or more whorls.
          f_1 Jaw smooth; shell glossy.....3. Cochlicopidae
          f_2 Jaw ribbed; southern animals.....8. Bulimulidae
      d_2 Jaw absent.....10. Oleacinidae
  b_2 Shell heliciform (Fig. 772) or depressed (except *Sphyradium*).
    c_1 Shell with a wide lip.
      d_1 Shell minute, less than 3 mm. in diameter.....4. Valloniidae
      d_2 Shell not minute, more than 6 mm. in diameter.....6. Helicidae
    c_2 Shell with a thin lip.
      d_1 Jaw without a median projection.....7. Endodontidae
      d_2 Jaw with a median projection.
        e_1 Teeth of radula thorn-shaped, in V-shaped rows.....9. Circinariidae
        e_2 Teeth both thorn-shaped and bicuspid and in straight rows..11. Zonitidae

* See "Nomenclature and Check List of North American Land Shells," by H. A. Pilsbry, Proc. Acad. Nat. Sci., Phila., 1889, p. 191. "Preliminary Outline of a New Classification of the Helices," by H. A. Pilsbry, same, 1892, p. 387. "Guide to the Study of the Helices," by H. A. Pilsbry, Vol. 9, Ser. 2, Man. of Conchology, 1894. "A Classified Catalogue of Am. Land Shells with Localities," by H. A. Pilsbry, Nautilus, Vol. 11, pp. 45 et seq., 1897-98. "On the Zool. Position of Partula and

a_2 External shell absent; slugs.
b_1 Animals marine.....1. ONCHIDIIDAE
b_2 Land animals.
c_1 Mantle confined to forward part of body.
d_1 Body with a mid-dorsal keel; jaw smooth.....12. LIMACIDAE
d_2 No keel or an indistinct one; jaw ribbed.....13. ARIONIDAE
c_2 Mantle covers entire back.....14. PHILOMYCIDAE

FAMILY 1. ONCHIDIIDAE.

Shell wanting; body ovoid, with no tentacles but with the eyes at the tips of a pair of stalks; mantle entirely covers the back; respiratory, anal, renal, and female genital pores at the hinder end of the body; male pore below the right eye stalk: 3 genera and species, which live mostly in shallow water along the seashore in warm countries, 2 on the Pacific coast.

ONCHIDELLA Gray. With the characters given above.

O. carpenteri Binney. Body oblong with rounded extremities and sides, and gray in color; no jaw; 5 mm. long and 3 mm. broad: Puget Sound to Gulf of California.

FAMILY 2. PUPILLIDAE.*

Small, often minute snails, with a more or less cylindrical or conical, blunt, multispiral shell; aperture small, usually contracted by internal teeth or lamellae; jaw smooth or finely striate, sometimes with accessory plate; umbilicus open; ureter straight: cosmopolitan; over 1,000 species, which live under or in decaying wood or leaves, usually in moist places; 50 American species.

Key to the genera of *Pupillidae* here described:

a_1 Shells pupiform (Fig. 788).
b_1 Aperture without teeth, or with but 1 or 2.
c_1 Shell cylindrical.....1. PUPILLA
c_2 Shell elongate and tapering.....2. PUPOIDES
b_2 Aperture with teeth.
c_1 Outer lip regularly rounded; 4 tentacles.
d_1 No tooth on columella.....1. PUPILLA
d_2 One or more teeth on columella.....3. BIFIDARIA
c_2 Outer lip indented above the middle; 2 tentacles.....4. VERTIGO
a_2 Shell heliciform (Fig. 772).....5. STROBILOPS

1. **PUPILLA** Leach. Shell minute, with impressed sutures, horn-color, and smooth; aperture with no teeth or with but 1 or 2 small ones and with an expanded and reflected lip; whorls 5 to 9; posterior

Achatinella," by H. A. Pilsbry, Proc. Acad. Nat. Sci., Vol. 52, p. 561, 1900. "Molluska of Michigan, Part 1, Terrestrial Pulmonata," by Bryant Walker, Rep. Geol. Sur., Mich., for 1905, p. 431.

* See "A Partial Revision of the Pupae of the United States," by H. A. Pilsbry and E. G. Vanatta, Proc. Acad. Nat. Sci., Phila., Vol. 52, p. 582. 1900.

tentacles long; anterior tentacles very short: cosmopolitan; numerous species, 6 American, mostly in the West.

P. muscorum (L.) (Fig. 788). Shell stout, cylindrical, with 6 or 7 whorls; aperture nearly circular, either without or with 1 or 2 teeth; length 4 mm.; breadth 1.5 mm.: North America; circumpolar.

2. **Pupoides** Pfeiffer. Shell rather slender and tapering, with 6 or 7 whorls, smooth and shining; aperture ovate, without teeth: in all continents except Europe; 3 American species.

P. marginatus (Say) (*P. fallax* Say) (Fig. 789). Jaw strongly arched; umbilicus deep; length 5 mm.; diameter 2 mm.: United States, east of the Rocky Mountains.

3. **Bifidaria** Sterki. Shell conical or ovate, smooth or finely striate; aperture dentate with usually a large bifid parietal lamella, 2 lipfolds, and a basal tooth; additional teeth sometimes present: about 22 American species.

Key to the species of *Bifidaria* here described:

a_1 Aperture almost edentate.....B. CORTICARIA
a_2 Aperture with prominent teeth.
b_1 Aperture nearly closed by 4 or 5 large teeth.....B. ARMIFERA
b_2 Aperture with 5 to 9 smaller teeth.....B. PENTODON

Fig. 788

Fig. 789

Fig. 790

Fig. 788—*Pupilla muscorum* (Morse). Fig. 789—*Pupoides marginatus* (Binney). Fig. 790—*Bifidaria corticaria* (Binney).

B. corticaria (Say) (Fig. 790). Shell white, shining, cylindrical, with an obtuse apex; whorls 5 to 6, convex; aperture with but 1 or 2 teeth on parietal wall, or none, and a very blunt tooth on the columellar wall; length 2.5 mm.; diameter 1 mm.: eastern states, to the Mississippi.

B. armifera (Say) (Fig. 791). Shell cylindrical, with 6 to 7 whorls; aperture with a wide rim and 4 to 6 teeth, the parietal lamellae large, irregular, with 1 or 2 projecting points; columellar lamella thick and situated deep in the aperture; lipfolds 2; length 4.5 mm.; diameter 2.2 mm.: from the Atlantic to the Rocky Mountains.

B. pentodon (Say). Shell conical, white, whorls 5, convex; aperture with a broad rim and with 8 teeth, the parietal and inferior lip lamella curved to the left; length 2 mm.; diameter 1 mm.: America.

4. **Vertigo** Draparnaud. Shell ovate or conical, with 4 to 6 convex whorls; apex obtuse; aperture with a narrow, white rim, the outer lip of which is usually straightened or indented at its upper third; with

4 to 7 teeth; anterior tentacles absent: a circumboreal genus, with about 36 American species.

Key to the species of *Vertigo* here described:

a_1 But 1 parietal tooth.....V. VENTRICOSA
a_2 Two parietal teeth.
b_1 Shell over 2 mm. long.....V. OVATA
b_2 Shell about 1 mm. long.....V. MILIUM

V. ovata Say (Fig. 792). Shell ovate, dark amber-colored, smooth, and shiny; outer lip of aperture indented; 6 to 12 teeth, 2 or 3 parietal, 2 columellar, and 2 to 6 on the lip; length 2.2 mm.; diameter 1.5 mm.: North America; the commonest species.

V. ventricosa (Morse). Shell ovate, smooth, and polished, with 4 whorls; lip of aperture with a deep indentation; teeth 5, 1 parietal, 2

Fig. 791

Fig. 792

Fig. 793

Fig. 791—*Bifidaria armifera* (Binney). Fig. 792—*Vertigo ovata* (Morse). Fig. 793—*Vertigo milium* (Morse).

columellar, and 2 on the lip; length 1.7 mm.; diameter 1.1 mm.: northeastern and north-central America; California.

V. milium (Gould) (Fig. 793). Shell ovate and very minute; dark amber in color; lip of aperture indented; teeth 6 to 8, 2 parietal, 2 columellar, 2 on lip, the upper one being large and sharply bent downwards at its inner end; length 1.4 mm.; diameter .8 mm.: America, east of the Mississippi River

5. **STROBILOPS** Pilsbry. Shell more or less heliciform with 5 or 6 striated whorls; parietal wall with several entering revolving lamellae: 5 American species.

Fig. 794—*Strobilops labyrinthica* (Walker).

S. labyrinthica (Say) (Fig. 794). Shell with 6 whorls, 2.1 mm. wide and 1.6 mm. high, with 3 parietal lamellae, each of which has swellings at regular intervals: eastern and central states.

FAMILY 3. COCHLICOPIDAE.

Shell elongate, slender, conical, without umbilicus; aperture edentate, rounded, or lengthened; ureter straight: 200 species, cosmopolitan.

COCHLICOPA Ferussac. Shell smooth and glossy; jaw slightly arched, without ribs and with a median projection: 2 American species

C. lubrica (O. F. Müller) (Fig. 795). Shell 6 mm. high, with 6 whorls, and yellowish in color: circumpolar; often common under dead leaves or decaying bark.

Family 4. VALLONIIDAE.

Shell minute, with a low depressed spiral, widely umbilicate, consisting of 3 or 4 whorls, the last of which is large and cylindrical; ureter straight: 1 genus.

Vallonia Risso. Aperture edentate, round; peristome reflected and white; jaw with numerous slight transverse ribs: 9 American species.

Fig. 795

Fig. 796

Fig. 797

Fig. 795—*Cochlicopa lubrica* (Binney). Fig. 796—*Vallonia pulchella* (Sterki). Fig. 797—*Vallonia costata* (Sterki).

V. pulchella (O. F. Müller) (Fig. 796). Height 1.3 mm.; diameter 2.6 mm.; shell thin, light colored, and transparent: circumpolar; northern states; often very common, under sticks, stones, and logs and in other dark, damp places.

V. costata (Müll.) (Fig. 797). Height 1.3 mm.; diameter 2.7 mm.; shell with regularly recurring transverse ribs; color gray: circumpolar; northern states.

Family 5. SUCCINEIDAE.

Shell very thin, with a small spire and a large, often flaring aperture; anterior tentacles very small or wanting; jaw with an accessory quadrangular median piece: 6 genera, 3 American.

Succinea Draparnaud. Shell fragile and transparent and not too small to contain the body; tentacles short and thick; foot broad; ureter reflexed: 200 species, on plants in wet places; 25 American species.

Key to the species of *Succinea* here described:

a_1 Aperture occupying the greater part of the shell.
  b_1 Aperture wide and oblique.....S. ovalis
  b_2 Aperture long, narrow, and straight.....S. retusa
a_2 Aperture round, occupying a little over half of the shell.....S. avara

S. ovalis Say (*S. obliqua* Say) (Fig. 798). Shell ovate, pale green or yellowish and shining, and minutely striated, with 3 whorls; spire small; aperture oblique and very large; length 28 mm.: eastern and central America; very common.

S. retusa Lea (*S. ovalis* Gould). Shell ovate, with 3 whorls, light yellowish or grayish and shining and minutely striate; spire short; aperture long and narrow; length 19 mm.; width 7 mm.: eastern and central states.

S. avara Say (Fig. 799). Shell elongate, with a long spire, yellowish, rosy, or greenish; whorls 3; suture very deep; length 11 mm.; width 4.5 mm.: North America; common; often under wet logs.

Fig. 798

Fig. 799

Fig. 798—*Succinea ovalis* (Binney). Fig. 799—*Succinea avara* (Baker).

FAMILY 6. HELICIDAE.

Shell with a rather low conical spire and consisting of 5 to 7 whorls; aperture either simple or with teeth, and with a wide reflexed lip; teeth of radula bicuspid and tricuspid; ureter reflexed; foot without marginal grooves: about 30 genera and several thousand species.

Key to the genera of *Helicidae* here described:

a_1 Dart sac, genital mucous glands, and flagellum present (Fig. 800)..1. HELIX
a_2 Dart sac, genital mucous glands, and flagellum absent (Fig. 801).2. POLYGYRA

1. HELIX* L. Shell heliciform (Fig. 772); jaw with prominent ribs; 1 or 2 dart sacs, genital mucous glands, and flagellum present (Fig. 800), although these organs may be rudimentary: many hundred species in the Palearctic region; poorly represented in America.

Fig. 800—Portion of the genital organs of Helix (Kingsley). 1, genital pore; 2, penis; 3, flagellum; 4, proximal portion of sperm duct; 5, proximal portion of oviduct; 6, proximal portion of spermatheca; 7, mucous glands; 8, dart sac.

H. aspersa O. F. Müller (Fig. 771). Shell yellowish or grayish, with brown revolving bands of varying widths; lowest whorl very large; aperture large, round, without teeth; height and diameter 22 mm.: an European species, which has been found in Portland, Maine, Charleston, S. C., and other places; California.

H. pomatia L. French snail. Edible snail. Shell rather thin, 5 cm. long and wide, yellowish-brown in color, often with several broad revolving bands; aperture without teeth; narrow, deep umbilicus pres-

* See "Land and Fresh Water Mollusks of Yucatan and Mexico," by H. A. Pilsbry, Proc. Acad. Nat. Sci., Phila., 1891, p. 313.

ent: an European species, introduced into New Orleans and other places: imported into New York for food.

H. hortensis (Müll.) (Fig. 802). Shell yellowish, usually striped with several revolving dark bands; aperture without teeth; peristome white; umbilicus closed; height 12 mm.: an European species, introduced into eastern New England.

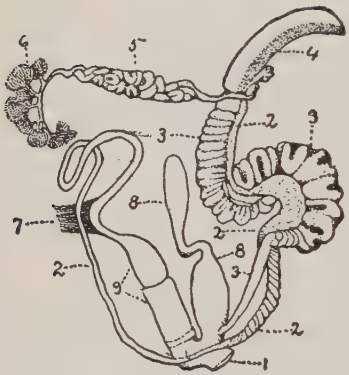

Fig. 801—Genital organs of Polygyra (from Walker). 1, genital pore; 2, sperm duct; 3, oviduct; 4, albuminous gland; 5, hermaphroditic duct; 6, hermaphroditic gland; 7, retractor muscle; 8 spermatheca; 9, penis.

H. nemoralis L. Like the above, with black peristome: an European species found at Burlington, N. J., and in Virginia in trees.

H. californiensis Lea. Shell variable in shape and color, globose, thin, and transparent, shining, pale yellowish, with a narrow, brown, revolving band, paler at its edges; height 15 mm.; diameter 19 mm.: California.

2. **Polygyra** Say. Shell heliciform (Fig. 722); aperture usually dentate, 1 tooth being parietal and 2 on the lip, but they may be absent; jaw with about a dozen prominent ribs; dart sac, genital mucous glands, and flagellum absent (Fig. 801); foot without marginal grooves: a North American genus with 125 species, which are most often found in moist and more or less open woodlands.

Key to the species of *Polygyra* here described:

a_1 Aperture tridentate.
  b_1 Aperture distinctly ear-shaped.....P. AURIFORMIS
  b_2 Aperture not ear-shaped.
    c_1 Umbilicus open.....P. TRIDENTATA
    c_2 Umbilicus closed.
      d_1 Diameter exceeding 20 mm.....P. PALLIATA
      d_2 Diameter less than 15 mm.....P. INFLECTA
a_2 Aperture unidentate.
  b_1 Aperture broad and more or less circular.
    c_1 Umbilicus open.....P. THYROIDES
    c_2 Umbilicus closed.....P. ALBOLABRIS
  b_2 Aperture very narrow.
    c_1 Surface of shell hirsute.....P. HIRSUTA
    c_2 Surface smooth.....P. MONODON
a_3 Aperture edentate.
  b_1 Shell without spiral lines.....P. ALBOLABRIS
  b_2 Shell with spiral lines.
    c_1 Umbilicus open.....P. PROFUNDA
    c_2 Umbilicus closed.....P. MULTILINEATA

P. auriformis (Bland) (Fig. 803). Shell white or yellowish, striated, with a very short spire, umbilicus open; aperture ear-shaped, contracted by 3 prominent teeth; height 6 mm.; diameter 11.5 mm.: Texas to Georgia; very common.

P. hirsuta (Say). Shell brownish and covered with rigid hairs; aperture very narrow, being contracted by an elongated tooth on the parietal wall; umbilicus closed; height 5 mm.; diameter 9 mm.: New England to Kansas, south to Virginia.

Fig. 802 Fig 803

Fig. 802—*Helix hortensis* (*Binney*). Fig. 803—*Polygyra auriformis* (Binney).

P. monodon (Rackett). Shell yellowish, umbilicus open or closed, aperture lunate, with an elongate tooth on the parietal wall; peristome white, reflected; height 6 mm.; diameter 11 mm.: eastern and central America; common, generally in groups of about a dozen.

P. profunda (Say) (Fig. 804). Shell depressed, with a wide umbilicus, and with numerous narrow revolving dark lines; color brownish or yellow; height 15 mm.; diameter 30 mm.: central states; abundant.

P. tridentata (Say). Shell with low, depressed, yellowish spire, with 5½ whorls and open umbilicus; aperture with 3 teeth; 8 mm. high; 16 mm. in diameter: eastern North America.

Fig. 804 Fig. 805

Fig. 804—*Polygyra profunda* (Baker). Fig. 805—*Polygyra albolabris* (Baker).

P. palliata (Say). Shell dark brown, with 5 whorls; aperture with white peristome and 3 teeth; umbilicus closed; height 10 mm.; diameter 21 mm.: eastern North America.

P. inflecta (Say). Shell, brown in color, striated, umbilicus closed; aperture contracted with 2 acute teeth on the inner margin of the peristome, and a long low tooth on the parietal wall; height 6.6 mm.; diameter 12 mm.: southern and central states west of the Alleghenies.

P. albolabris (Say) (Fig. 805). Shell yellowish-brown in color, with 5 or 6 whorls; umbilicus closed; aperture without teeth or with a slight one on the parietal wall; peristome flat, white, and very widely reflected; height 24 mm.; diameter 30 mm.: usually very common in eastern and central United States.

P. multilineata (Say). Shell yellowish-brown, striped with numerous narrow revolving dark bands; aperture without teeth; peristome

narrow; umbilicus closed; height 14 mm.; diameter 23 mm.: America west of the Alleghenies and south of central Michigan.

P. thyroides (Say) (Fig. 806). Shell depressed, thin, yellowish-brown; aperture with a prominent white tooth on parietal wall; umbilicus narrow and partially covered by the reflected peristome; height 18 mm.; diameter 22 mm.: eastern and central America.

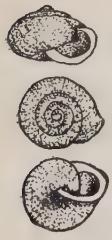

Fig. 806 *Polygyra thyroides* (Baker).

Family 7. ENDODONTIDAE.

Shell conical or depressed, ribbed or striated, usually with brown markings, and with open umbilicus; lip thin and sharp, usually without teeth: 4 American genera.

Key to the genera of *Endodontidae* here described:

a_1 Jaw composed of a single piece.
  b_1 Spire raised, but low.....1. Pyramidula
  b_2 Shell discoid.....2. Helicodiscus
a_2 Jaw composed of numerous overlapping pieces; shell heliciform (Fig. 772).....3. Punctum

1. Pyramidula Fitzinger. Shell with 5 or 6 whorls and a wide umbilicus; aperture rounded and large, usually without teeth; foot with marginal grooves which meet behind; dart sac, mucous genital glands, and flagellum absent; jaw not ribbed, but striated: cosmopolitan; about 12 American species.

Key to the species of *Pyramidula* here described:

a_1 Shell without prominent transverse ribs.
  b_1 Shell color with markings.
    c_1 Shell with 2 or 3 revolving bands.....P. solitaria
    c_2 Shell with broken, irregular transverse bands. P. alternata
  b_2 Shell color plain.....P. perspectiva
a_2 Shell with prominent transverse ribs.....P. asteriscus

Fig. 807 *Pyramidula solitaria* (Baker).

P. solitaria (Say) (Fig. 807). Shell elevated, white or reddish, striped with 2 or 3 broad revolving brown bands; height 19 mm.; diameter 25 mm.: America, north of the Ohio River; Oregon and Washington.

P. alternata (Say). Shell depressed, yellowish, with oblique and broken red bands; height 10 mm.; diameter 21 mm.: eastern and central America; abundant in decaying logs and other damp places; gregarious.

P. perspectiva (Say). Shell flattened, thin, brownish; aperture small, often with a single small tooth; height 3 mm.; diameter 8 mm.: eastern and central America, but not east of the Alleghenies north of Maryland.

P. asteriscus (Morse). Shell very flat, with 25 or 30 prominent transverse ribs on the whorls; height .5 mm.; diameter 1.5 mm.: New England and Canada; California.

2. Helicodiscus Morse. Shell disc-shaped, with the spire flat, and the umbilicus broad and shallow, the last whorl with 1 or more internal teeth; jaw crescentic, with a median projection: 2 American species.

H. parallelus (Say) (*H. lineatus* Say) (Fig. 808). Height 1.5 mm.; diameter 4 mm., with parallel, raised, revolving lines: eastern United States, living under leaves, loose bark, etc.

3. Punctum Morse. Shell depressed and discoidal, small or minute; aperature large, with a thin lip and without teeth; jaw composed of 16 to 19 separate quadrate plates: circumpolar; 6 American species.

P. pygmæum (Draparnaud) (Fig. 809). Umbilicus open; shell minute; height 1 mm.; diameter 1.5 mm.: eastern United States.

Family 8. BULIMULIDAE.

Shell elongate, with a high conical spire; aperture elongate, edentate; jaw arched with prominent ribs; radula with central tricuspid and lateral bicuspid teeth; ureter reflexed: over 1,000 species, principally in tropical America.

Fig. 808

Fig. 809

Fig. 810

Fig. 808—*Helicodiscus parallelus* (Binney). Fig. 809—*Punctum pygmæum* (Binney). Fig. 810—*Bulimulus dealbatus* (Binney).

Bulimulus Leach. With the characters of the family: about 6 species in the United States, all southern.

B. dealbatus (Say) (Fig. 810). Shell thin, white, with gray longitudinal lines, 6 or 7 whorls; aperture oval, with an acute lip; 18 mm. long; 12 mm. thick: southern states, north to North Carolina and Missouri; common.

Family 9. CIRCINARIIDAE.

Shell either internal or external and heliciform, thin, with a wide umbilicus, depressed, with 5 whorls; aperture large, with a somewhat thickened lip; jaw crescentic, striated, with a median projection; radula with long thorn-like teeth, the animals being carnivorous; ureter reflexed: 12 American species, all on Pacific slope but one.

Fig. 811 *Circinaria concava* (Baker).

Circinaria Beck. Shell external: several species.

C. concava (Say) (Fig. 811). Height 8 mm.; diameter 17 mm.; color whitish: eastern and central states.

C. vancouverensis Lea. Height 14 mm.; diameter 31 mm.; color yellowish: Washington, Idaho, and northwards.

Family 10. TESTACELLIDAE.

Shell variable in shape, animal long and slug-like; jaw absent; radula with long thorn-like teeth, the animal being carnivorous; ureter reflexed: about 12 genera.

Fig. 812
Euglandina rosca (Binney).

1. Testacella Cuvier. Shell very small and rudimentary, and ear-shaped, and carried on the back near the hinder end: 7 species, principally in western Mediterranean countries.

T. haliotoidea (Férussac). Length of shell 7 mm.; breadth 4.5 mm.; body of animal 5 times as long: greenhouses in Philadelphia and other cities, where it feeds on worms, snails, etc.

2. Euglandina Férussac. Shell tall and conical, with 6 to 8 whorls; tentacle-like lip on each side of mouth: tropical America; 4 species in the southern states.

E. rosea Fér. (*E. truncata* Gmelin) (Fig. 812). Shell 37 mm. long or more and 13 mm. thick, and fluted with longitudinal ridges: South Carolina to Texas; it leads a semi-aquatic life, feeding largely on snails.

Family 11. ZONITIDAE.

Shell thin and delicate, usually depressed, often very small; usually with umbilicus; jaw smooth or nearly so, with a median projection; aperture large with a thin lip; foot with marginal grooves and caudal mucous gland; ureter reflexed: cosmopolitan; 65 American species, which live under dead leaves, rotting logs, and in other similar places.

Key to the genera of *Zonitidae* here described:

a_1 Dart sac and mucous genital glands absent.
  b_1 Whorls 2 or 3; no umbilicus.....2. Vitrina
  b_2 Whorls 4 or more; usually with umbilicus.
    c_1 Spire depressed.
      d_1 Shell 15 mm. or more in diameter, smoky in appearance...1. Omphalina
      d_2 Shell small, glassy in appearance.....3. Vitrea
    c_2 Spire high.....4. Euconulus
a_2 Dart sac and genital mucous glands present (Fig. 800).
  b_1 Internal teeth or a calcareous deposit on floor of largest whorl.
    6. Gastrodonta
  b_2 No internal teeth; umbilicus wide.....5. Zonitoides

1. Omphalina Rafinesque. Shell striated above, smooth below, with umbilicus; last whorl dilated; aperture broad, with an acute lip: about 14 species, all North American.

O. fuliginosa (Griffith) (Fig. 813). Shell depressed, thin, glossy, and dark colored, with 4½ whorls and with a deep umbilicus; height 13 mm.; diameter 26 mm.: eastern and central states.

Fig. 813

Fig. 814

Fig. 813—*Omphalina fuliginosa* (Baker). Fig. 814—*Vitrina limpida* (Binney).

2. **Vitrina** Draparnaud. Shell small, not entirely enclosing the animal, with a low spire, thin and shining, and 2 to 3 whorls, the last large, with a large aperture and a thin lip: cosmopolitan; 100 species, 3 American, all northerly.

V. limpida Gould (Fig. 814). Height 3 mm.; diameter 6 mm.: western Pennsylvania, and to the west and north of it.

3. **Vitrea** Fitzinger. Shell thin, smooth, and shining, depressed with 4 to 6 whorls; animal black dorsally: 21 American species.

Fig. 815 *Vitrea hammonis* (Binney).

V. hammonis (Ström) (Fig. 815). Shell with a narrow umbilicus, brownish in color; 2.5 mm. high and 5 mm. wide: entire country, south to South Carolina; common; Europe.

V. indentata (Say). Shell highly polished, without umbilicus, but with umbilical region indented; 2.5 mm. high and 5 mm. wide: entire country.

4. **Euconulus** Reinhardt. Shell with a very narrow umbilicus or with none, with rather high spire of 5 or 6 whorls: 3 American species.

E. fulvus (O. F. Müller) (Fig. 816). Shell smooth and shining, light yellowish in color; 3 mm. high and 4 mm. in diameter; color of animal black: circumpolar; entire country; very common.

Fig. 816 *Euconulus fulvus* (Walker).

5. **Zonitoides** Lehmann. Shell depressed, with wide umbilicus, smooth or ribbed, shining; aperture large, without teeth; long dart sac present: 15 American species.

Key to the species of *Zonitoides* here described:

a_1 Surface of shell smooth.
b_1 Diameter 7.5 mm. ..... Z. NITIDA
b_2 Diameter 5 mm. ..... Z. ARBOREA
a_2 Surface striated or ribbed; shell minute.
b_1 Surface striated ..... Z. MINUSCULA
b_2 Surface folded and reticulated ..... Z. MILIUM

Z. nitida (O. F. Müller). Shell elevated, with polished, yellowish surface and 5 whorls; 3.6 mm. high and 7.5 mm. in diameter; animal black: northern states and Canada; common on the banks of streams; Europe.

Z. arborea (Say). Shell depressed, amber-colored, polished, with 5 whorls; deep and narrow umbilicus; 2.75 mm. high and 5 mm. in diameter; head and neck black, rest of body white: entire country, the commonest species, living gregariously under bark, leaves, etc.

Z. minuscula (Binney). Shell depressed, with 4 whorls, with a very wide umbilicus; aperture circular, with an acute lip; height 1 mm.; diameter 2.5 mm.: entire United States; common.

Z. milium (Morse). Shell depressed, with a broad umbilicus, striated, with 3 whorls; height .5 mm.; diameter 1.5 mm.: entire United States; common.

6. Gastrodonta Albers. Shell usually with an umbilicus, with 5 to 7 whorls and yellowish in color; aperture lunate, with an acute lip, either with internal teeth not reaching the margin or thickened by an internal calcareous deposit; animal black, with a long dart sac and mucous genital glands: 19 American species.

Fig. 817
Gastrodonta ligera (Binney).

G. suppressa (Say). Shell depressed, with a large whorl, thin; aperture rather large; lip thickened by a white deposit within it and with 1 or 2 parallel ridges; height 5 mm.; diameter 8 mm.; umbilicus small or rudimentary: eastern and central states.

G. ligera (Say) (Fig. 817). Shell with a rather high spire; aperture thickened within; height 10 mm.; diameter 15 mm.: central states.

Family 12. LIMACIDAE.

Slugs. No external shell present, but a rudimentary shell in form of a thin calcareous plate in the mantle; body elongate and tapering; mantle not extending back of the middle of the body; jaw without ribs and with a median projection; ureter reflexed: about 20 genera and several hundred species, which live in gardens and woods, in moist places, and are nocturnal in their habits; 6 American species.

Key to the genera of *Limacidae* here described:

a_1 Large slugs, with spots.....1. Limax
a_2 Small slugs, unspotted.....2. Agriolimax

1. Limax L. Body tapering and keeled behind, terminating with a point; jaw with blunt ends: cosmopolitan.

Key to the species of *Limax* here described:

a_1 Spots white.....L. flavus
a_2 Spots and blotches black.....L. maximus

L. flavus L. Color yellowish or brownish, with oblong uncolored spots; body covered with long, narrow tubercles; head bluish; length 85

mm. or more: an European species present locally in many places in the eastern states.

L. maximus L. (Fig. 818). Color gray, with alternate longitudinal rows of spots and stripes of black, replaced by irregular blotches on the mantle; dirty white below; body covered with coarse, elongated tubercles; length 16 cm.: an European species present locally in many places in the eastern states; California.

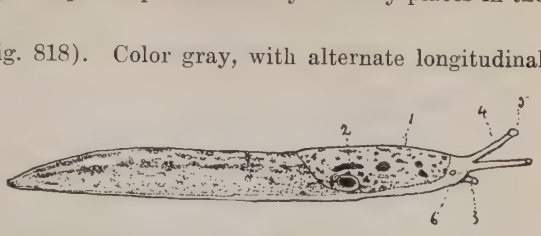

Fig. 818—*Limax maximus* (Baker). 1, mantle; 2, respiratory pore; 3, anterior tentacles; 4, posterior tentacles; 5, eye; 6, genital pore.

2. **Agriolimax** Mörch. Body keeled behind and unspotted; jaw with blunt ends: animals live under stones and decaying wood and feed on leaves, etc.; they can suspend themselves by threads of mucous from bushes and trees.

Fig. 819—*Agriolimax campestris* (Binney). 1, mantle; 2, posterior tentacles.

A. campestris (Binney) (Fig. 819). Color uniformly grayish or amber, often blackish; upper surface covered with prominent tubercles, not flattened; mantle oval; mucous watery; length 25 mm.: common in eastern and central America, under logs, damp leaves, etc.; California.

A. agrestis (L.). Upper surface covered with flat, gray, or brown tubercles, separated by darker-colored anastomosing grooves; mantle pore bordered with white; mucous milky; length 25 to 50 mm.: eastern America; California; an European species locally present in many places.

Family 13. ARIONIDAE.*

Slugs. No external shell, but the small shield-like mantle usually encloses a calcareous rudiment of one; body elongate, limaciform; jaw with prominent ribs; foot with marginal furrows; ureter reflexed: 4 genera; about 15 American species, mostly on the Pacific slope.

1. **Arion** Férussac. Body ending obtusely behind; back covered with elongated tuberosities arranged in rows, and not keeled; mantle oval and covered with granulations containing calcareous particles, which represent the shell; mantle pore anterior: 25 species, all in the Old World.

A. hortensis Fér. Color gray or yellowish or black; length 5 cm.: an European species, which occurs locally in New England and other places.

* See "Revision of North American Slugs," by H. A. Pilsbry and E. G. Vanatta, Proc. Acad. Nat. Sci., Phila., 1896, p. 339; also 1898, p. 219.

2. **Ariolimax** Mörch. Body tapering and somewhat keeled: 6 species, all on the Pacific slope.

A. columbianus (Gould). Color greenish-yellow, sometimes blotched with darker patches; length 15 cm.: Washington, Oregon, and California, in damp forests.

A. niger Cooper. Color nearly black, sometimes gray; length 5 cm.: central California.

Family 14. PHILOMYCIDAE.

Slugs. No internal or external shell; body limaciform, with the mantle covering the entire back and tapering behind; no caudal mucous pore; ureter reflexed: 2 genera; 5 American species.

Fig. 820—*Philomychus carolinensis* (Binney). 1, mantle; 2, respiratory pore.

1. **Philomycus** Férussac. Jaw smooth, strongly arched and with a median projection; respiratory pore near the head; foot with marginal grooves.

P. caroliniensis (Bosc) (Fig. 820). Color whitish with dark spots and blotches; length 7 cm.: eastern and central states, in forests in trees, under bark, or in rotten wood, being partial to basswood.

2. **Pallifera** Morse. Jaw with stout ribs on its anterior surface, and without a median projection.

P. dorsalis (Binney). Color ashy, with an interrupted mid-dorsal line; jaw with 9 ribs; length 18 mm.: northeastern and central states.

P. hemphilli (Binney). Color black; jaw with 4 or 5 ribs: central states; rare.

Order 3. **PROSOBRANCHIATA.** (Streptoneura.)

Mostly marine snails, in which the ctenidium lies in the mantle cavity at the forward end of the body (Fig. 828, 1) and in front of the heart. In a few primitive forms (*Zygobranchiata*) a pair of ctenidia is present. The *Helicinidae* and *Proserpinidae* are without gills and the ctenidium is replaced by a lung, the animals beng terrestrial. Near the ctenidium in the inner surface of the mantle is the hypobranchial gland, which, in *Murex* and *Purpura,* becomes the purple gland; its function is unknown. With rare exceptions the animal is provided with a shell, which is often of large size and is sometimes very thick and heavy, and in many forms very beautifully marked and colored. The operculum is almost invariably present, and is either calcareous or horny, and either spiral or annular.

The foot forms a broad sole, except in the *Heteropoda:* in a few forms it can envelop the shell (*Natica*). The head, which often projects snout-like forwards, bears a single pair of non-retractile tentacles and a pair of eyes, which are either at the base of or on the tentacles or at the tips of stalks of their own. The higher prosobranchs are distinguished by the possession of a proboscis, which can often be thrust out far in advance of the animal, and also a siphon, which is formed by a prolongation of the anterior margin of the mantle, and in many snails lies in a characteristic prolongation of the shell called the anterior or siphonal canal (Fig. 872, 1). Paired jaws are present in the non-carnivorous forms, the carnivorous ones being destitute of jaws. The radula varies much among the different groups and is wanting in the *Gymnoglossa.*

The nervous system is streptoneurous, the pleurovisceral connectives crossing each other. The sexes are separate, the male being usually distinguished by a slenderer shell. The eggs are laid usually in capsules (Fig. 879), which vary much among the various forms, and are often attached to rocks or other objects. *Littorina* deposits its eggs in a jelly. The fresh-water *Viviparidae* bear their young alive.

The *Prosobranchiata* include about 27,500 living species, mostly marine, which are grouped under two suborders.

Key to the suborders of *Prosobranchiata:*

a_1 Gill bipectinate (Fig. 821, B) or absent, shell without siphonal canal (Fig. 872, 1) ..... 1. SCUTIBRANCHIATA
a_2 Gill monopectinate (Fig. 821, C) ..... 2. PECTINIBRANCHIATA

SUBORDER 1. SCUTIBRANCHIATA. (ASPIDOBRANCHIATA; DIOTOCARDIA.)

Snails with a primitive structure, a pair of ctenidia being present in the *Zygobranchiata,* and in all others the bipectinate ctenidia, where present, projecting freely anteriorly (Fig. 821, B); 2 auricles and 2 kidneys generally present, the gonad opening to the outside through the right kidney (except in the *Neritidae*); proboscis, siphonal canal, and penis absent: 17 families, grouped in 2 divisions, inhabiting the sea, fresh water, and the land.

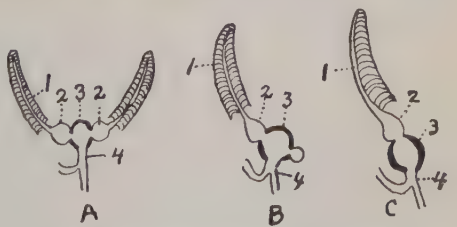

Fig. 821—Prosobranch gills. A, paired; B, bipectinate, and C, monopectinate gills (Lang). 1, branchial vein; 2, auricle; 3, ventricle; 4, aorta.

Key to the divisions of *Scutibranchiata:*

a_1 Shell conical and not spiral, and without a slit or hole ..... 1. DOCOGLOSSA
a_2 Shell mostly spiral, but when not so with slits or holes .... 2. RHIPIDOGLOSSA

Division 1. DOCOGLOSSA.

Limpets. Shell conical and not spiral; 2 osphradia; 1 auricle; 1 ctenidium or none; mantle margin often fringed (*Patella*); jaw median and unpaired; no operculum; radula very long, with but few hooked teeth in each transverse row: 3 families, with 1,500 species, all marine and occurring mostly in shallow water.

Family ACMÆIDAE.

Ctenidium present, projecting from the left to the right; apex of shell usually inclined anteriorly: 1 species on the Atlantic and several on the Pacific coast.

Acmæa Eschscholtz. Shell solid and not iridescent within; tentacles rather long and cylindrical; anus on the right; lips frilled and elongated at the lower anterior corners; radula with 2 centrals; mantle margin not fringed: about 40 species.

Fig. 822 *Acmæa testudinalis* (Verrill).

A. testudinalis (L.). Common limpet (Fig. 822). Shell depressed, smooth, gray or greenish in color, with dark brown stripes radiating from the apex; inner surface whitish, with a large brown spot; length 35 mm.; width 25 mm.; height 9 mm.: circumpolar, south to Long Island Sound and to Sitka; common north of Cape Cod on rocks in shallow water; a smaller, narrow, spotted variety (*A. alvea* Conrad) is attached to eel grass; Europe.

A. patina Eschs. Shell 53 mm. long, 46 mm. wide, and 18 mm. high; surface with radiating striations, grayish; inside white, with a large, brown central area: entire Pacific coast; the commonest Californian limpet.

Division 2. RHIPIDOGLOSSA.

Shell usually spiral, the spire being in most cases low and little coiled; jaw paired; radula long; teeth, 1 central, 3 to 9 laterals, and very many crowded marginals; 1 or 2 ctenidia; 2 auricles; 2 kidneys: 14 families, in the sea, fresh water, and on the land, grouped in 2 subdivisions.

Key to the subdivisions of *Rhipidoglossa:*

a_1 Shell and mantle with slits or holes: 2 ctenidia.....1. Zygobranchiata
a_2 Shell without slits or holes; 1 ctenidium.....2. Azygobranchiata

Subdivision 1. ZYGOBRANCHIATA.

Shell and mantle with a marginal or an apical slit, or with marginal holes; 2 ctenidia (Fig. 821, A): 3 families, all marine.

Key to the families of *Zygobranchiata* described:

a_1 Shell patelliform (like Fig. 822).....1. Fissurellidae
a_2 Shell spiral and flat; aperture very wide.....2. Haliotidae

Family 1. FISSURELLIDAE.

Keyhole limpets. Shell non-spiral, conical; either anterior margin notched or apex perforated; 2 symmetrical ctenidia; foot very large, with an epipodial ridge on each side, which bears a series of cirri; no operculum: several hundred species.

Fissurella Bruguière. Apex of shell perforated; shell wholly external, capable of containing the whole animal: 125 species, mostly in warm waters.

Fig. 823 *Fissurella barbadensis* (Rogers).

F. barbadensis Gmelin (Fig. 823). Shell oval, perforation almost circular; surface with radiating ribs, of which about 11 are larger than the others; color grayish inside, with alternately green and white concentric rings; margin crenulated; length 37 mm.; width 24 mm.; height 9.5 mm.: Florida, Bermuda, and West Indies; common.

F. volcano Reese. Shell oval; orifice a little in front of the middle and oblong; color grayish, with 13 to 16 radiating purplish rays; length 25 mm.; width 17 mm.; height 10 mm.: Santa Cruz, California, and southwards.

Family 2. HALIOTIDAE.

Ear shells. Shell ear-shaped, the spire being flat and the aperture enormously expanded, and perforated with a spiral series of holes near the left margin; no operculum; eyes on stalks near the outer base of the tentacles; foot very large, surrounded by fringed and tentacled epipodia, which project beyond the edge of the shell and through the holes; right gill smaller than the left: 1 genus and about 100 species; the animals are eaten in many places, and the shells are much sought after on account of their beauty and for use in the manufacture of buttons and buckles and for inlaying.

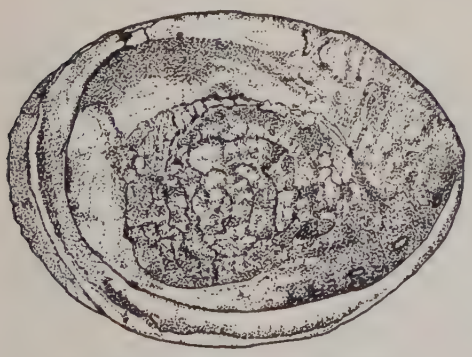

Fig. 824—*Haliotes fulgens* (Rogers).

Haliotis L. Abalones. With the characters of the family: Pacific and Indian oceans and Europe; about 5 species on the Pacific coast, living in shallow water. There is large export trade in the shells and flesh of these animals, the latter being dried and sent to Japan and China, the shells to Europe.

H. rufescens Swainson. Red Abalone. Shell large and thick, 23 cm. long, 18 cm. wide, brick red in color outside and pinkish or greenish inside; 3 or 4 perforations: California, south of Cape Mendocino; common.

H. fulgens Philippi. Green Abalone (Fig. 824). Shell thin, 15 cm. long, iridescent green in color; about 6 perforations: California, south of Monterey.

H. cracherodi Leach. Black Abalone. Shell 12 cm. long, 10 cm. wide, with 8 perforations, black outside: common south of the Farallone Islands.

Subdivision 2. AZYGOBRANCHIATA.

But 1 ctenidium (Fig. 821); shell usually with an elevated spire: marine, fresh-water, and terrestrial; 11 families.

Key to the families of *Azygobranchiata* here described:

a_1 Animals marine.
b_1 Operculum horny; shell conical.....1. Trochidae

b_2 Operculum calcareous.
c_1 Spire not very small.....2. Turbinidae
c_2 Spire very small.....3. Neritidae

a_2 Animals terrestrial or in fresh water.
b_1 Spire very small.....3. Neritidae
b_2 Spire not very small.....4. Helicinidae

Family 1. TROCHIDAE.

Shell usually conical, multispiral, with a flattened base, pearly inside; operculum horny, multispiral; snout short; eyes on stalks at outer base of the long tentacles, and fringed lobes present on the head and foot: about 20 genera and over 1,000 species, all marine.

Key to the genera of *Trochidae* here described:

a_1 Shell pyramidal.
b_1 Umbilical indentation present.....1. Trochus
b_2 Without such indentation.....2. Calliostoma
a_2 Shell conical or globose.....3. Margarita

Fig. 825—*Calliostoma annulatum* (Rogers).

1. Trochus L. Shell pyramidal, with a flat base and flattened whorls; aperture small, oblique, pearly, with a thin outer lip; umbilicus indented: 250 species, cosmopolitan, many with beautiful shells.

T. niloticus L. Shell 7.5 cm. long; 9 cm. wide; thick, smooth, white, with brownish markings: Indian Ocean; often used as ornaments.

2. Calliostoma Swainson. Shell pyramidal, with a flat base, without umbilicus; interior pearly: 28 species.

C. annulatum Martin (Fig. 825). Shell 30 mm. long and wide, thin, light brown in color, with purple sutures: California.

3. **Margarita** Leach. Shell small, thin, conical or globose, with open umbilicus; whorls rounded and smooth: 24 species, in colder waters.

Key to the species of *Margarita* here described:

a_1 Shell solid, with 2 or 3 revolving ridges.....M. OBSCURA
a_2 Shell thin.
b_1 Shell with regular spiral lines.....M. UNDULATA
b_2 Shell yellowish in color.....M. HELICINA

M. obscura Couthouy (Fig. 826). Shell small, with a low, conical spire and brownish in color; whorls 5, with 2 or 3 revolving ridges; these with the coarse lines of growth give the shell an indented appearance; length 10 mm.; diameter 12 mm.: Long Island Sound to Labrador, in rather deep water towards the south, but in shallow water towards the north; common.

Fig. 826 *Margarita obscura* (Tryon).

M. undulata (Sowerby). Shell thin, conical, brownish or red in color, but lusterless; whorls 6, with short wrinkles near the suture, and with numerous elevated spiral lines at regular intervals; length 7.5 mm.; diameter 10 mm.: Cape Cod to the Arctic Ocean, from low-water mark to deep water; Europe; common.

M. helicina (Fabricius). Shell small, thin, light yellowish or pinkish in color, very bright and polished; whorls 4 or 5, very convex; aperture large and circular; length 5 mm.; diameter 7.5 mm.: circumpolar, south to Cape Cod and Vancouver; in deep water, but often thrown up on beaches.

Fig. 827—*Turbo marmoratus* (Rogers).

Family 2. TURBINIDAE.

Shell large, spiral, conical, with a large lower whorl and aperture; operculum calcareous and spiral: 100 species, mostly tropical; about 8 species on the Pacific coast.

1. **Turbo** L. Shell turbinate, with rounded whorls; aperture round: 76 species.

T. marmoratus L. (Fig. 827). Green snail. Shell 11 cm. long and 12 cm. wide; bright green, pearly inside; lip expanded, forming on the columella a wide extension: Indian Ocean; used extensively as an ornament and in the manufactures.

Family 3. NERITIDAE.

Shell thick, semi-globose, with a small spire and a very large lower whorl and aperture; operculum calcareous; cavity simple in consequence of the absorption of the internal portions of the whorls; animal with a broad, short snout; tentacles slender; eyes stalked; epipodium not fringed: many hundred species, mostly marine, a few in fresh water and terrestrial.

Nerita L. Shell smooth or spirally ridged; outer lip thick, usually with teeth within: over 200 species, which live on rocks, feeding on algae.

N. fulgurans Gmelin. Shell with spiral ridges, black or gray in color; aperture white, with prominent teeth; 18 mm. long; 30 mm. wide: West Indies; California.

Family 4. HELICINIDAE.

Shell conical or depressed, heliciform, with a single cavity due to the absorption of the inner portions of the whorls; columella generally with a thick callus, which covers the umbilicus; lip thick; operculum oval or triangular; tentacles slender, with eyes at their base; ctenidia absent, the mantle cavity being transformed into a lung: over 500 species, all terrestrial, chiefly in warm countries; about 4 species in the southern states (70 species in Cuba).

Helicina Lamarck. With the characters of the family: about 350 species in tropical America and the Pacific islands.

H. orbiculata Say. Shell yellowish in color, sometimes spotted, with 5 whorls; 6 mm. high; 9 mm. in diameter: southern states, south of Tennessee.

Suborder 2. PECTINIBRANCHIATA. (Monotocardia; Ctenobranchiata.)

But one auricle, kidney, osphradium, and ctenidium present, the ctenidium being monopectinate or feathered on but one side (Fig. 821, C) and attached to the mantle its whole length (except in *Janthina* and *Valvata*); proboscis, siphon, anterior or siphonal canal, and penis usually present; gonad never opens into the kidney but has a separate duct: over 50 families, grouped in 5 divisions and comprising most of the prosobranchs.

Key to the divisions of *Pectinibranchiata:*

a_1 Radula short and wide, with numerous lateral and usually no central teeth; shell without siphonal canal.....1. Ptenoglossa

a_2 Radula long and narrow, or wanting; siphonal canal either present or absent.

b_1 Radula with 7 teeth in each transverse row (Fig. 830); canal present or not; the majority of species.....2. Taenioglossa

b_2 Radula and jaw wanting; shell elongate, without canal...3. Gymnoglossa

b_3 Radula with 3 teeth in each row (Fig. 870); shell thick, conical, with canal .....4. Rachiglossa

b_4 Radula with 1 or 3 teeth in each row; shell with an elongate aperture and a canal.....5. Toxoglossa

Division 1. PTENOGLOSSA.

Shell conical or discoid, with a small, simple aperture; no siphonal canal; radula with or without central tooth, but with numerous small laterals: 3 families, all marine.

Key to the families of *Ptenoglossa* here described:

a_1 Animal pelagic.....1. Janthinidae
a_2 Animals littoral.....2. Scalariidae

Family 1. JANTHINIDAE.

Shell thin and transparent, heliciform; 2 free ctenidia; foot small, secreting a long vesicular float, which supports the animal at the surface of the water, and to which the eggs are attached; when handled, the animal exudes a violet fluid: 12 species, in warm waters, pelagic, gregarious, feeding largely on jellyfish.

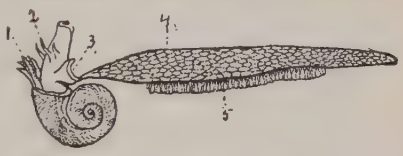

Fig. 828—*Janthina fragilis* (Cambridge Natural History). 1, gill; 2, tentacles; 3, foot; 4, float; 5, eggs.

Janthina Lamarck. With the characters of the family: about 4 species off the Atlantic and 1 off the Pacific coast.

J. fragilis Lam. (Fig. 828). Shell 20 mm. high; diameter 25 mm.; color violet: tropical and pelagic, sometimes thrown up on the shores of New England.

Family 2. SCALARIIDAE.

Fig. 829

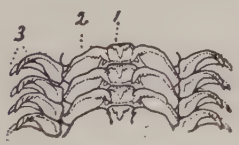

Fig. 830

Fig. 829—*Scala lineata* (Verrill). Fig. 830—Radula of Vermetus (Cambridge Natural History). 1, central; 2, lateral; 3, marginals.

Spiral staircases. Wentletraps. Shell an elongated cone, white, with many very convex whorls, which are crossed by elevated ribs; operculum horny; a short siphon present; the animal exudes a purple fluid: about 4 genera and 200 species.

Scalaria Lamarck. With the characters of the family: numerous species on the Atlantic coast, mostly in deep water and towards the south.

S. grœnlandica Perry. Shell rather long and tapering, 25 mm. long and 9 mm. thick; whorls 10; ribs white, on a whitish or brown surface, which has 6 or 8 revolving ridges: Cape Cod to the Arctic Ocean, in 10 to 100 fathoms; often common; Europe.

S. lineata Say (Fig. 829). Shell long and tapering; 12 mm. long and 5 mm. thick; whorls 11: Cape Cod to Florida; common towards the south.

S. angulata Say. Shell 20 mm. long, 8 mm. wide; whorls 6 to 11, touching one another only by the ribs: Long Island Sound to Texas, common towards the south.

Division 2. TÆNIOGLOSSA.

Shell very variable in shape, with or without siphonal canal; radula (Fig. 830) long and narrow, with 1 central, on each side of which are 1 lateral and 2 marginal teeth, making 7 in each row: about 50 families, grouped in 2 subdivisions, including most prosobranchs.

Key to the subdivisions of *Tænioglossa:*

a_1 Foot with a broad sole.....1. Platypoda
a_2 Foot fin-shaped; animals pelagic.....2. Heteropoda

Subdivision 1. PLATYPODA.

Shell well developed; foot with a broad sole, with which the animals creep: 48 families, marine and in fresh water.

Key to the families of *Platypoda* here described:

a_1 Aperture rounded, without siphonal canal (Fig. 831, 2).
b_1 Animals marine.
c_1 Shell regularly coiled or much flattened.
d_1 Shell not long and slender, but more or less globose or flattened.
e_1 Shell conical and with a distinct spire (Fig. 772, 3).
f_1 Umbilicus open (Fig. 831, 1) or more or less closed by a large calius. 1. Naticidae
f_2 Umbilicus closed.....3. Littorinidae
e_2 Shell either not spiral or much flattened.
f_1 Spiral either absent or very inconspicuous.....2. Capulidae
f_2 Shell spiral, but discoid.....6. Skeneidae
d_2 Shell elongate with a high spire.
e_1 Shell minute, less than 5 mm. long, with 5 or 6 whorls.....4. Rissoidae
e_2 Shell very long, with about 10 whorls.....12. Turritellidae
c_2 Shell with a very irregular spiral.....13. Vermetidae
b_2 Animals in fresh water.
c_1 Shell usually minute, less than 5 mm. long, and always less than 10 mm.
d_1 Shell usually elongate and conical.....5. Hydrobiidae
d_2 Shell usually flattened and discoid.....8. Valvatidae
c_2 Shell not small, usually much more than 12 mm. long; heliciform (Fig. 772).
d_1 Snout simple; tentacles short.....7. Viviparidae
d_2 Snout divided into 2 long tentacular lobes; tentacles long. 9. Ampullariidae
a_2 Aperture elongate, with siphonal canal (Fig. 872, 1).
b_1 Canal short (Fig. 854), sometimes consisting only of the narrowed lower edge of the aperture.
c_1 Surface ridged or tuberculated.....10. Cerithiidae
c_2 Surface usually smooth.....11. Pleuroceridae
b_2 Canal long; aperture usually long and narrow (Fig. 859).
c_1 Spire low or hidden; aperture nearly as long as the shell.
d_1 Spire almost or entirely hidden.....15. Cypræidae
d_2 Spire free and raised.
e_1 Shell thick, with thick reflexed lips.
f_1 Outer lip with a notch near the lower end.....14. Strombidae
f_2 Outer lip without a notch.....17. Cassididae
e_2 Shell thin, with a thin lip.....16. Doliidae
c_2 Spire high; aperture not half as long as shell.....18. Tritonidae

Family 1. NATICIDAE.

Shell usually globose or flattened, with a short spire; aperture round or lunar; lip sharp; umbilicus open, or closed by a callus; operculum usually corneous; foot very large and capable of being swollen by the taking in of sea water into open spaces and reflected back over the shell so as almost to cover it; tentacles small, lanceolate, wide apart, united by a veil; eggs deposited in a "sand collar," a thin collar-shaped lamella formed by agglutinating grains of sand together by means of mucous: several hundred species.

Key to the genera of *Naticidae* here described:

a_1 Shell globose.....1. Natica
a_2 Shell flattened with a very large aperture.
b_1 Shell ear-shaped.....2. Sigaretus
b_2 Shell trumpet-shaped.....3. Velutina

1. Natica Lamarck. Shell smooth and regular, gray or brownish in color, with about 5 whorls; eyes wanting; umbilicus usually more or less closed by a large callus: over 200 species; predacious animals, living in the sand, where they burrow after bivalves; they envelop their prey in the foot and penetrate its shell, drilling a hole with the radula; they also devour dead fish; about 20 species on the Atlantic coast.

Key to the species of *Natica* here described:

a_1 Shell over 25 mm. long.
b_1 Umbilicus wide and deep.....N. heros
b_2 Umbilicus nearly closed by a brown callus.....N. duplicata
a_2 Shell 15 mm. or less long.
b_1 Umbilicus wide and deep.....N. immaculata
b_2 Umbilicus more or less covered by a white callus.
c_1 Shell 8 mm. or less long.....N. pusilla
c_2 Shell over 10 mm. long.
d_1 Shell with minute revolving lines.....N. grœnlandica
d_2 Shell without revolving lines.....N. clausa

N. (*Polynices* Montfort) **heros** Say (Fig. 831). Shell large and moderately thick; whorls 5, convex; umbilicus large and deep; length 9 cm.; diameter 8 cm.; shell ash color, streaked with chestnut: Virginia to Labrador; from low-water mark to 238 fathoms; common.

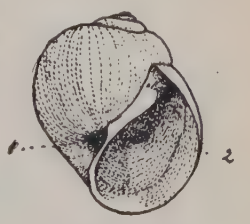

Fig. 831
Natica heros (Verrill).
1, umbilicus; 2, aperture.

N. (*Polynices* Montfort) **duplicata** Say. Shell solid, whorls 5, flattened above; spire low; color ashy gray, tending towards brown on the upper side, chestnut brown within; callus very large, chestnut brown in color, almost filling the umbilicus; length and diameter 5½ cm.: Massachusetts Bay to Mexico; common in shallow water.

N. pusilla Say (Fig. 832). Shell thin and small, often streaked with brown; callus white, and pressed laterally into the umbilicus, which is nearly closed; length 6 mm.; diameter 5 mm.: Massachusetts to west Florida; common in shallow water.

Fig. 832
Natica pusilla (Verrill).

N. (*Polynices* Montfort) **immaculata** Totten. Shell solid and small; umbilicus rounded and deep, but little covered by the small callus; color yellowish, and white beneath; length 7 mm.; diameter 5.5 mm.: Long Island Sound to the Gulf of St. Lawrence, in shallow water; often common.

N. grœnlandica Möller. Shell small, smooth, glossy, bluish-white, with minute revolving lines; 12 mm. long; 11 mm. in diameter; callus white, nearly filling the umbilicus, leaving only a narrow, curved opening: Cape Cod, northwards.

N. clausa Broderip. Shell small, whitish or brownish, without revolving lines; 15 mm. long; 13 mm. in diameter; callus white, completely filling the umbilicus; operculum calcareous: circumpolar, south to Cape Cod and Vancouver; common.

2. **Sigaretus** Lamarck. Shell flat and ear-shaped, with a minute spire and an enormously expanded aperture; mantle large, partly or entirely covering the shell; operculum minute, horny; propodium enormously developed, used for burrowing: 100 species, 3 on the Atlantic coast.

S. perspectivus Say (Fig. 833). Shell oval, flattened, white, smooth, and polished; 37 mm. long; 30 mm. wide: New Jersey to Florida; common in shallow water.

Fig. 833

Fig. 834

Fig. 833—*Sigaretus perspectivus* (Rogers).
Fig. 834—*Velutina lævigata* (Rogers).

3. **Velutina** Blainville. Shell small, thin, covered with a velvety periostracum; spire minute; lower whorl large, with a circular aperture; no operculum: 2 species, on the Atlantic coast.

V. lævigata (L.) (*V. haliotoidea* Fabricius) (Fig. 834). Shell very thin and fragile, transparent, pinkish; whorls 3; length 12 mm.; diameter 10 mm.: Cape Cod, northwards.

Family 2. CAPULIDAE.

Shell conical, flat, or boat-shaped, with scarcely any spiral, or none at all; interior with a shelf, variously formed, to which the adductor muscles are attached; no operculum; head distinct, with a

lengthened snout; the animal adheres by means of the broad foot to stones and shells, and does not move about: 7 genera and 160 species.

Key to the genera of *Capulidae* here described:

a_1 Shell conical; partition cup-shaped.....1. CRUCIBULUM
a_2 Shell with a slight spiral; partition more or less horizontal....2. CREPIDULA

1. CRUCIBULUM Schumacher. Shell, conical and not spiral, with the apex directed posteriorly; shelf more or less cup-shaped, attached to the inner wall near the apex, on one side: cosmopolitan.

Fig. 835 *Crucibulum striatum* (Verrill).

C. striatum (Say) (Fig. 835). Cup-and-saucer limpet. Shell solid, with numerous elevated radiating lines; aperture circular; white or yellowish in color; 12 mm. in height and 20 mm. in diameter: Florida to Bay of Fundy; in 2 to 189 fathoms; common in shallow water towards the north.

2. CREPIDULA* Lamarck. Shell oval, boat-shaped or flat, with the inconspicuous spire at the hinder end; shelf an internal regular plate in the hinder half of the shell: 50 species, in all the warmer seas; attached to shells, seaweed, etc.

Key to the species of *Crepidula* here described:

a_1 Shell convex.
b_1 Shell up to 45 mm. long; shelf white.....C. FORNICATA
b_2 Shell 12 mm. long or less; shelf brown.....C. CONVEXA
a_2 Shell flat.....C. PLANA

Fig. 836—*Crepidulum fornicata* (Verrill).

C. fornicata (L.) (Fig. 836). Shell convex, with one side more curved than the other; color whitish or brownish; shelf concave, white; length 45 mm.; width 33 mm.; height 15 mm.: Nova Scotia to South America, in shallow water, very abundant; Europe.

C. convexa Say. Shell very convex, the short side being nearly vertical; color whitish or brownish; shelf deep-seated, convex, brown in color, with a white edge; length 12 mm.; width 8 mm.; height 4 mm.: Nova Scotia to Florida, in shallow water; not so abundant as the above; Pacific coast.

C. plana Say. Shell flat or concave, with a minute apex; white and polished inside; length 40 mm.; width 25 mm.: Maine to Texas; common in shells from low-water mark to 487 fathoms.

FAMILY 3. LITTORINIDAE.

Shell spiral and conical; lip not notched; aperture round, interior not pearly; operculum horny and spiral; head projecting, tentacles

* See "The Embryology of Crepidula," by E. G. Conklin, Jour. Morph., Vol. 13, 1897.

conical, with eyes at their base: several hundred species, in salt, brackish, and fresh water, some being amphibious; they are mostly littoral, and feed on algae, on which they are found.

Key to the genera of *Littorinidae* here described:

a_1 Shell thick and solid; no umbilicus.....1. LITTORINA
a_2 Shell thin.....2. LACUNA

1. LITTORINA Férussac. Periwinkles. Shell conical, thick and solid, with 4 to 6 whorls; lip acute; no umbilicus; foot longitudinally divided, each side advancing alternately when the animal moves; radula 2 or 3 times the length of the animal: 175 species, cosmopolitan; in shallow water; more or less amphibious.

Key to the species of *Littorina* here described:

a_1 Shell not smooth and shining.
b_1 Shell with revolving color bands.
c_1 Bands continuous.....L. LITOREA
c_2 Bands broken.....L. IRRORATA
b_2 Shell without color bands.....L. RUDIS
a_2 Shell smooth and shining.....L. PALLIATA

L. litorea (L.). The edible periwinkle (Fig. 837). Shell not smooth, dark brown, yellowish, or reddish in color, with dark spiral bands; interior white or brown; length 25 mm.; width 16 mm.: Europe, where it is an article of food; recently introduced on our Atlantic coast, and now very common as far south as Delaware Bay.

Fig. 837

Fig. 838

Fig. 839

Fig. 837—*Littorina litorea* (Leunis). Fig. 838—*Littorina rudis* (Verrill). Fig. 839—*Lacuna vincta* (Verrill).

L. rudis (Donovan) (Fig. 838). Shell very solid and thick, with usually spiral ridges and grooves, whitish to red or black in color, with sometimes spiral bands; shell very variable in color and texture; length 14 mm.; width 10 mm.: New Jersey to the Arctic Ocean; very common; Pacific coast; Europe.

L. irrorata (Say). Whorls flattened, yellowish-white or green in color, with numerous revolving ridges which are spotted with short brown lines; throat white; length 25 mm.: Vineyard Sound to Florida, very common towards the south.

L. palliata (Say). Shell small with a low spire; surface smooth and shining; color yellow, brown, or red, sometimes spirally banded; length 15 mm.: New Jersey to the Arctic Ocean; very common; Europe.

2. Lacuna Turton. Shell conical and thin with about 5 whorls, with a long umbilical groove along the columella leading to a deep umbilicus: 16 species.

L. vincta (Montagu) (Fig. 839). Shell gray or yellowish in color, with 2 dark bands on the upper whorl and 4 on the lower one, which may be wanting; length 12 mm.; diameter 7 mm.: circumpolar, south to Long Island Sound and Puget Sound; very common; Europe.

Family 4. RISSOIDAE.

Shell small, spiral, turreted; aperture regularly rounded, with a slightly-expanded lip; operculum horny; eyes at the base of the tentacles; epipodium with filaments: marine or brackish water; over 200 species, principally towards the south.

Rissoa Fréminville. Shell minute, conical, multispiral, white in color: 75 species, mostly in the north temperate zone in deep water.

Fig. 840
Rissoa aculeus (Verrill).

R. minuta (Totten). Shell thin and polished, with 5 whorls and an obtuse apex; color yellowish, which is usually coated with a green pigment; length 4 mm.; diameter 2 mm.: New Jersey to Gulf of St. Lawrence; common on seaweed and under stones.

R. aculeus (Gould) (Fig. 840). Shell thin, with 6 whorls, light yellowish in color, with microscopic revolving lines; length 4 mm.; diameter 1.7 mm.: Long Island Sound to Greenland; common on seaweed.

Family 5. HYDROBIIDAE.

Shell small, usually elongate and conical, with a pointed spire; aperture rounded; operculum corneous or calcareous; umbilicus usually open: about 80 species, in fresh and brackish water; cosmopolitan.

Key to the genera of *Hydrobiidae* here described:

a_1 Shell ovate.
  b_1 Umbilicus closed.
    c_1 In eastern and central states.....1. Bythinia
    c_2 On Pacific slope.....3. Fluminicola
  b_2 Umbilicus open.
    c_1 Spire well developed.....2. Amnicola
    c_2 Spire very low.....4. Somatogyrus
a_2 Shell elongate.
  b_1 Umbilicus narrow and deep.....5. Pomatiopsis
  b_2 Umbilicus absent or very shallow.....6. Paludestrina

1. Bythinia Gray. Shell conical, thin, covered with a thin periostracum; operculum calcareous, not spiral, but with prominent growth-ridges: in fresh water; 50 species, all in the Old World.

B. tentaculata (L.) (Fig. 841). Shell yellowish or greenish in color, smooth and shining, with 5 whorls, the lowest of which equals the other four; length 11 mm.; width 6.5 mm.: a European species introduced recently into the northern states; in lakes and ponds, often very common; in Chicago they are sometimes drawn into the water pipes from Lake Michigan in sufficient quantities to block the smaller ones.

Fig. 841 Fig. 842

Fig. 841—*Bythinia tentaculata* (Baker). Fig. 842—*Amnicola limosa* (Baker).

2. **Amnicola** Gould and Haldeman. Shell small, thin, smooth, conical, with a low spire and a broad lower whorl; operculum spiral, horny; snout short, tentacles long: about 10 species, all in North America, in fresh water; 3 on the Pacific slope.

A. limosa (Say) (Fig. 842). Shell globose, plain brown in color, without bands, shining, 5 mm. long, 4 mm. wide; umbilicus either narrow or wide; whorls 4 to 5; aperture circular; lip sharp: entire country; very common on the muddy bottom or on aquatic plants in streams and ponds.

A. cincinnatiensis (Lea). Shell swollen, greenish or yellowish-brown in color, smooth and shining, 5.5 mm. long, 4 mm. wide; whorls 5 or 6; aperture oval; lip sharp; umbilicus small and very deep: eastern and central states; common on the muddy bottom of streams and ponds.

3. **Fluminicola** Stimpson. Shell rather large, ovate, solid, without umbilicus, smooth, outer lip projecting above over the inner lip, which is flattened: Pacific slope, in streams and lakes.

F. nuttalliana (Lea). Shell yellowish, smooth, with 4 whorls; aperture white; length 10 mm.; diameter 7.5 mm.: valley of the Columbia; very common.

4. **Somatogyrus** Gill. Shell globose, with a short low spire and a very large inflated lower whorl and large oblique aperture; whorls 4; lip thin; operculum spiral, horny: about 6 species, all in the central states, in fresh water.

Fig. 843 *Somatogyrus subglobosus* (Baker).

S. subglobosus (Say) (Fig. 843). Shell yellowish in color, shining; apex rounded; length 7 mm.; width 6.5 mm.; umbilicus small: central states, west to Iowa.

S. integer (Say). Shell yellowish, shining, 4 mm. long and 3 mm. wide; umbilicus almost obliterated by a callus: central states, west to Iowa.

5. **Pomatiopsis** Tryon. Shell small, elongate, and conical; umbilicus narrow and deep; aperture round or oval; operculum spiral and corneous; peristome thin: North America; air breathers, although possessed of a gill.

P. lapidaria (Say) (Fig. 844). Shell slender, dark brown in color, and shining, with 6 whorls, 6.5 mm. long and 3 mm. wide: eastern and central states, under stones on the margin of streams or in moist places on land or on aquatic plants; common.

Fig. 844 *Pomatiopsis lapidaria* (Baker).

P. cincinnatiensis (Anthony). Shell robust, with 4 or 5 whorls, greenish or brown in color, and shining, 4.5 mm. long and 2.3 mm. wide: central states, in moist places on land, or on stones in the water.

P. californica Pilsbry. Shell thin, brown in color, 5 mm. long: San Francisco and Oakland.

6. **Paludestrina** D'Orbigny. Shell small, elongate, conical, with an elevated spire; apex generally obtuse; aperture ovate; lip thickened; operculum horny: in fresh water.

P. nickliniana (Lea) (Fig. 845). Shell with 6 whorls, greenish in color, shining, 4.5 mm. long, 2 mm. wide; umbilicus indented: eastern and central states; often common on aquatic vegetation in ponds and rivers.

Family 6. SKENEIDAE.

Shell small, with a very low spire, being almost discoidal, and a wide umbilicus; operculum horny, multispiral: 1 genus, in northern seas.

Skenea Fleming. With the characters of the family: 1 American species.

Fig. 845

Fig. 846

Fig. 847

Fig. 845—*Paludestrina nickliniana* (Baker). Fig. 846—*Skenea planorbis* (Verrill). Fig. 847—*Vivipara contectoides* (Baker).

S. planorbis (Fabricius) (Fig. 846). Shell minute, flat, with 3 whorls, yellowish, smooth; aperture circular; length .8 mm.; width 1.3 mm.: Long Island Sound to Greenland; common under stones near low-water mark; Pacific coast; Europe.

Family 7. VIVIPARIDAE. (Paludinidae.)

Shell conical or globose, with rounded whorls and an olive-green periostracum; aperture simple, roundish; operculum horny and usually not spiral; animal with a prominent, broad snout, and eyes on short stalks at the outer base of the stout tentacles; viviparous, the young remaining in the parent shell for some time after hatching: about 6 genera and over 200 species; in fresh water in all parts of the world.

Key to the genera of *Viviparidae* here described:

a_1 Shell banded, with umbilicus.....1. VIVIPARA
a_2 Shell not banded, without umbilicus.
b_1 Shell thick and solid.....2. CAMPELOMA
b_2 Shell thin.....3. LIOPLAX

1. VIVIPARA Lamarck (*Paludina* Lam.). Shell thin, with about 5 whorls and a small umbilicus: 100 species, cosmopolitan; about 8 American species, mostly in the southern states; about 2 on the Pacific slope.

V. contectoides Binney (Fig. 847). Shell with 4 revolving brown bands, of which 3 are on the body of the whorl and 1 on the base, the upper whorls showing but 2 bands, sometimes indistinct or wanting; length 33 mm.; width 25 mm.: eastern and central states, in lakes and rivers, on muddy bottoms in shallow water.

2. CAMPELOMA* Rafinesque. Shell solid, thick, without umbilicus; whorls 6: about 6 species, all in North America.

Fig. 848
Campeloma ponderosum (Baker).

Key to the species of *Campeloma* here described:

a_1 Spire shorter than the aperture.....C. PONDEROSUM
a_2 Spire and aperture of equal length.
b_1 Whorls rounded.....C. DECISUM
b_2 Whorls flattened.....C. SUBSOLIDUM

C. ponderosum (Say) (Fig. 848). Shell very heavy and solid, conical, with a very large lower whorl and an elongate ovate aperture; color greenish or blackish; length 21 mm.; width 15 mm.; aperture longer than the spire: New York to Illinois, south to Alabama.

C. decisum (Say). Shell rather solid, conical; spire about as long as the aperture; length 28 mm.; width 17 mm.; color dark green, surface shining: New England to Iowa; south to Tennessee.

C. subsolidum (Anthony). Shell very solid, yellowish or light green in color, smooth; whorls 6, flattened; aperture sigmoid; length 40 mm.; width 23 mm.: New England to Illinois, south to central Ohio.

3. LIOPLAX Troschel. Shell thin, conical, and elongate; without umbilicus; foot very large: 2 species, both in the United States.

L. subcarinata (Say). Shell with 3 or 4 whorls, which are with 2 or 3 indistinct ridges; operculum spiral in the center, except in old shells; aperture oval; length 12 mm.; width 10 mm.; color greenish: New Jersey to Indiana.

FAMILY 8. VALVATIDAE.

Shell small, conical, and depressed or discoidal, with an open umbilicus; operculum corneous, circular, multispiral; periostracum

* See "On the Genus Campeloma," etc., by R. E. Call, Bull. Washburn Coll. Lab., Vol. 1, p. 149, 1886.

greenish; tentacles long and slender with eyes at their outer base; snout prolonged; ctenidium bipectinate, long, exposed; animals hermaphroditic: the temperate regions of the globe, in rivers, ponds, and lakes; 1 genus.

Valvata O. F. Müller. With the characters of the family: about 6 American species, 3 being on the Pacific slope.

Key to the species of *Valvata* here described:

a_1 Whorls of shell rounded.....V. SINCERA
a_2 Whorls keeled.
b_1 Apex elevated.....V. TRICARINATA
b_2 Apex not elevated.....V. BICARINATA

V. sincera Say (Fig. 849). Shell conical and depressed, with 3 or 4 whorls; spire very low; lowest whorl very large, rounded; aperture round, beneath the rest of the shell; surface shining and brownish in color; length 2.5 mm.; width 4.5 mm.: Canada and Alaska and the northern states towards the north; in lakes and sluggish streams.

Fig. 849

Fig. 850

Fig. 849—*Valvata sincera* (Baker). Fig. 850—*Valvata tricarinata* (Baker).

V. tricarinata (Say) (Fig. 850). Shell depressed, thin, shining, whitish or greenish in color, with an elevated spire flattened at the apex; whorls 3 or 4, with deep sutures, and with 1 to 3 prominent keels on the outer surface; length and width 4 mm.: northern states, south to Iowa; very common.

V. bicarinata Lea. Shell discoid, the spire not elevated, and with no more than 2 keels; length 3.5 mm.; width 5 mm.: northern states.

Family 9. AMPULLARIIDAE.

Shell with a low spire and a large lower whorl and aperture; snout divided into two long tentacular lobes; tentacles long and slender, with eyes on short stalks at their outer base; mantle with a long siphon on the left side; respiratory cavity divided by a partition, the left acting as a pulmonary sac, the right containing a very large ctenidium: numerous species; in fresh water, principally in tropical regions.

Ampullaria Lamarck. With the characters of the family; umbilicus widely open: 150 species.

A. depressa Say. Shell with 4 whorls, yellowish in color, with numerous revolving brown or greenish bands; 37 mm. long and wide: Florida and Georgia, in rivers and lakes.

Family 10. CERITHIIDAE.

Shell elongate, with a tall spire and a ridged or tuberculated surface; aperture channeled in front, forming a short canal, and usually

with an expanded outer lip; operculum horny and spiral; mantle with a short siphon: 200 species, in salt, brackish, and fresh water.

Key to the genera of *Cerithiidae* here described:

a_1 Shell dextral.
b_1 Outer lip not expanded.....1. BITTIUM
b_2 Outer lip expanded.....3. CERITHIOPSIS
a_2 Shell sinistral.....2. TRIFORIS

1. BITTIUM Leach. Shell with a granular surface; aperture with a slight canal in front; outer lip acute, not expanded; operculum with 4 spirals: numerous species.

B. alternatum (Say) (*B. nigrum* Stimpson) (Fig. 851). Shell slender, with about 8 whorls, bluish or blackish in color, 6 mm. long and 2 mm. wide; surface covered with a fine network of elevated lines; aperture rounded: Massachusetts Bay to New Jersey; in shallow water.

Fig. 851
Bittium alternatum (Verrill).

2. TRIFORIS Deshayes. Shell sinistral; aperture round, prolonged in front to form a closed tube: 100 species, mostly towards the south.

T. perversa (L.) (*T. nigrocincta* Adams). Shell reddish-black in color, with 3 revolving series of granules; whorls 12 or more; length 7 mm.; width 1.7 mm.: Cape Cod to west Florida; rather common; Europe; California.

Fig. 852
Cerithiopsis greeni (Verrill).

3. CERITHIOPSIS Forbes and Hanley. Shell slender, frequently with longitudinal ribs; aperture with an anterior canal and a less distinct posterior one; operculum horny and spiral: in shallow water.

C. greeni (Adams) (Fig. 852). Shell with 10 to 12 whorls, reddish-black in color, with longitudinal ridges and revolving lines, forming series of granules; length 5 mm.; width 1.2 mm.: Massachusetts Bay to Texas.

C. terebralis (Adams). Shell with 10 to 12 whorls, flattened and having 3 revolving ridges on each, with numerous fine longitudinal lines between the ridges; length 12 mm.; width 3 mm.; color reddish-brown: Cape Cod to Texas.

FAMILY 11. PLEUROCERIDAE.

Shell elongate, conical, with numerous whorls; operculum spiral; aperture round or ovate, and rather small and channeled or angulated in front; animal with a broad, short snout and with eyes sessile, situated at the base of the tentacles: in fresh water; many hundred species, all in the United States (except 2 or 3 in Mexico), mostly in the southern states.

Key to the genera of *Pleuroceridae* here described:

a_1 Aperture lengthened to form a short canal; whorls flattened. 1. PLEUROCERA
a_2 Aperture not canaliculate; whorls rounded..... 2. GONIOBASIS

1. PLEUROCERA Rafinesque. Shell with a long, tapering spire; outer lip with a projection about the middle forming a short siphonal canal; surface smooth or ribbed; without umbilicus: 84 species.

P. subulare (Lea) (Fig. 853). Shell yellowish-brown in color, with a yellowish band encircling the whole just below the suture; whorls 11, increasing regularly, the upper 7 with a slight revolving ridge, the lower 4 rounded; length 22 mm.; width 8 mm.: upper Mississippi and valley of the Great Lakes, usually on sandy or rocky bottoms.

P. elevatum (Say) (Fig. 854). Shell yellowish or greenish in color, with a yellowish band just below the suture and two purplish bands

Fig. 853

Fig. 854

Fig. 855

Fig. 853—*Pleurocera subulare* (Baker). Fig. 854—*Pleurocera elevatum* (Baker). Fig. 855—*Goniobasis livescens* (Baker).

at the center of the whorls; whorls flattened, with revolving ridges; aperture triangulate: chiefly in the drainage of the Ohio River, on sandy or rocky bottoms.

2. GONIOBASIS Lea. Shell rather heavy, elongated, with a long and more or less pointed spire; aperture not channelled: 274 species.

G. livescens (Menke) (Fig. 855). Shell pinkish, yellowish, or greenish in color, often with two dark brown bands; surface shining, with a slight revolving ridge in the center of all the whorls but the last 2; length 20 mm.; width 9.5 mm.; whorls 7 to 9, rounded; aperture ovate, purple inside; outer lip very convex and elongated below: valley of the Great Lakes; in shallow water containing vegetation.

G. virginica (Gmelin). Shell slender, dark brown in color; length 30 mm.; whorls 6, somewhat rounded: Delaware and Schuylkill Rivers; common.

FAMILY 12. TURRITELLIDAE.

Shell elongate, with a very long spire on which are revolving ridges; no umbilicus; operculum multispiral and horny; tentacles long, with eyes at their base; mantle fringed, with a siphon; aperture round, without a canal: 190 species; marine.

Turritella Lamarck. Aperture round; shell usually brown, with brownish spots: 75 species; cosmopolitan; mostly in deep water.

T. acicula Stimpson. Shell small, white, and thin, with 10 whorls, 6 mm. long; 2 mm. wide. Cape Cod to Eastport, Maine, in rather deep water.

T. variegata (L.). Shell 10 cm. long, with 16 flattened whorls; surface variegated with brown and white: Florida and West Indies.

Family 13. VERMETIDAE.

Shell tubular, irregularly spiral at the apex, with the lower whorls free and extended; interior of shell partitioned off by smooth, concave septa; aperture round; foot rudimentary; head long, with 2 conical tentacles with eyes at their base; 2 additional tentacles at the side of the mouth; operculum circular, horny; animals stationary: 120 species, in all temperate and warm seas.

Vermetus Adanson. With the characters of the family; shell attached or free: numerous species.

V. (*Vermicularia* Lamarck) **radicula** Stimpson (Fig. 856). Spiral portion with about 8 whorls and 12 mm. long, remainder of shell sometimes 20 cm. long: Cape Cod to Florida in shallow water, several shells usually intertwined together; common towards the south.

Fig. 856 *Vermetus radicula* (Verrill).

Family 14. STROMBIDAE.

Shell usually large and solid, with a conical spire and a very large lower whorl; aperture long and narrow; lip expanded, sometimes forming digitations, and with a deep notch near the lower edge; foot long and narrow, with a long arched metapodium which bears the small claw-shaped operculum, and used for springing and not for walking; eyes large, at the end of a pair of long stalks; snout long: 100 species, in tropical and subtropical seas; several species in the West Indies and southern states.

1. **Strombus** L. Shell ovate, usually with protuberances; lip plain or lobed: 60 species, 5 American.

S. gigas L. Conch. Length 25 cm. and more; weight up to 5 pounds; surface roughened and with protuberances; interior pink: Florida Keys and West Indies; very common; used for food; the shell is used to make cameos and ornaments, and also often as a dinner horn; the largest shell on the Atlantic coast and the largest mollusk in the country.

S. pugilis L. (Fig. 857). Length 9.5 cm.; color reddish-brown; spire acute, with protuberances; interior pink: Cape Hatteras to Panama, in shallow water.

Fig. 857
Strombus pugilis (Rogers).

2. **Pterocera** Lamarck. Outer lip of shell with long finger-like processes: 10 species in Pacific and Indian Oceans.

Fig. 858—*Pterocera lambis* (Rogers).

P. lambis (L.). Finger shell (Fig. 858). Length 15 cm.; 6 fingers and a finger-like siphonal canal present: Indian Ocean; used as ornaments.

3. **Aporrhais** Dillwyn. Shell with a tall spire; aperture large; lip very much thickened and expanded, the outer lip being widely dilated: 4 species, in the North Atlantic.

A. occidentalis Beck. Shell solid, conical, with 9 whorls which have arched, transverse ridges; outer lip dilated and wing-like; color whitish; length 6 cm.; width 35 mm.: Cape Cod, northwards, occasionally found on the beach.

Family 15. CYPRÆIDAE.

Shell solid, ovate, very smooth and polished, and often brightly colored; spire often concealed by the last whorl, which is then as long as the shell; aperture narrow and channeled at each end; no operculum; foot broad; mantle expanded on each side and meeting over the back: several hundred species, mostly in tropical and subtropical seas.

1. **Cypræa** L. Cowries. Shell ovate, flattened beneath, with the spire concealed; aperture toothed on both sides; outer lip turned in: 200 species, mostly in the Indian and Pacific Oceans, where the beautiful shells are much used for ornaments.

Fig. 859—*Cypræa moneta* (Rogers).

C. moneta L. (Fig. 859). True cowry. Shell yellow to white in color; 3 cm. long: Indian and Pacific Oceans; very common; used in Africa and other places as money.

C. exanthema L. Shell brown in color, with round white spots which may have brown centers, and a mid-dorsal yellow band; lip violet within; length 11 cm.: Cape Hatteras to Panama, in shallow water.

C. spadicea Gray. Nut-brown cowry. Shell dark brown above and lighter in the center; lips white; length 5 cm. or less: California; not common.

2. **Trivia** Gray. Coffee-bean shells. Similar to Cypræa, but with transverse ribs, and much smaller: 45 species; cosmopolitan.

T. californica Gray. Shell reddish-chocolate in color and white inside, with a dozen sharp ribs; length 10 mm.: California, in shallow water.

Fig. 860 *Trivia pediculus* (Rogers).

T. pediculus (L.) (Fig. 860). Shell pinkish, with 6 black spots on the back and 20 mm. long: Florida.

3. **Ovulum** Bruguière. Shell spindle-shaped, the aperture being drawn out at both ends into a canal; inner lip smooth; outer lip toothed or smoth: 75 species; in tropical seas.

Fig. 861—*Orulum ovum* (Rogers).

O. ovum (L.) (Fig. 861). Shell egg-shaped, white, with a yellow aperture; length 9.5 cm.: Indian Ocean; used for ornaments.

Family 16. DOLIIDAE.

Shell large, thin, with a short spire and a very large swollen whorl, and covered with revolving ridges; operculum wanting; head long and wide; proboscis very long; foot very large: about 30 species; in tropical seas; shell often used as domestic utensils.

Dolium L. Shell ovate; outer lip crenulated: 15 species, 4 on the South Atlantic coast.

D. galea L. (Fig. 862). Shell brownish-yellow in color, with rounded revolving ribs; length 25 cm.: Cape Hatteras to Texas; the West Indies, in shallow water; Mediterranean.

Family 17. CASSIDIDAE.

Shell thick, triangular or fusiform; spire short, partially immersed; aperture long and narrow, terminating below in a short curved canal; columella covered with a broad callus; outer lip broad, ribbed within; operculum horny: 60 species, in tropical seas; about 7 on the South Atlantic coast.

Cassis Lamarck. Shell solid, last whorl very large; canal short and bent backwards: 37 species, which are much used in cutting cameos.

C. cameo Stimpson. Length 25 cm.; yellowish-white, tinged with yellowish-brown; lip and columella very broad, yellowish-cream color, with dark brown teeth and ridges: North Carolina to west Florida; West Indies.

Fig. 862

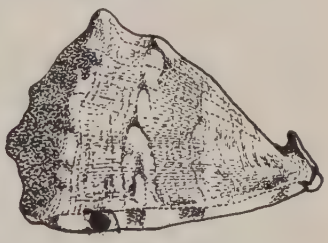

Fig. 863

Fig. 862—*Dolium galea* (Rogers). Fig. 863—*Cassis tuberosa* (Rogers).

C. tuberosa (L.) (Fig. 863). Length 20 cm.; surface crossed by numerous fine grooves, both longitudinal and spiral; color yellow, with brown blotches; lower whorl with 3 rows of protuberances: North Carolina to west Florida; West Indies.

Family 18. TRITONIDAE.

Shell solid, conical or fusiform, with a high spire; surface rough; outer lip thickened and turned in; operculum horny; aperture with a canal: 150 species, in tropical seas.

Triton Montfort. Tritons. Shell conical, with a crenulated outer lip; whorls roughened by transverse and longitudinal ridges: 100 species, in tropical seas; the largest snails, the shells being often used as trumpets.

T. nodiferus Lamarck. Length 45 cm.; color brown and white; aperture red: Mediterranean Sea, East Atlantic, Indian, and Pacific Oceans; often used as a shepherd's horn or a war horn.

T. tritonis (L.) (Fig. 864). Length up to 50 cm.; color brown, white, and red; aperture red: Gulf of Mexico; Indian Ocean.

Fig. 864
Tritonium tritonis (Leunis).

Subdivision 2. HETEROPODA.

Pelagic, transparent prosobranchs in which the foot is a swimming organ, and is made up of two parts, a compressed fin-like structure

(propodium and mesopodium) which projects ventrally and often bears a sucker, and a tail (metapodium) which projects posteriorly, and in some forms bears an operculum; head large, bearing a pair of tentacles with large eyes on short stalks at their base; the principal viscera form a sort of nucleus, often brightly colored, dorsally situated and covered, in most cases, by a transparent shell; sexes separate: about 60 species, all of which live on the high sea, often in large schools, in tropical and subtropical regions, eating fishes, crustacea, and other small animals; 2 families.

Key to the families of *Heteropoda:*

a_1 Shell much too small to contain the animal and sometimes absent. 1. PTEROTRACHEIDAE

a_2 Shell multispiral, containing the body.....2. ATLANTIDAE

FAMILY 1. PTEROTRACHEIDAE.

Body elongate, cylindrical, transparent, naked or with a small, transparent, conical, cap-shaped shell which covers the small nucleus alone, and from which projects the ctenidium: 4 genera and about 30 species.

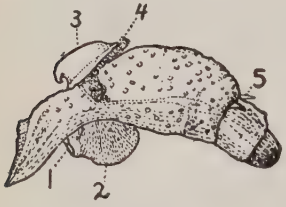

Fig. 865

Fig. 866

Fig. 867

Fig. 865—*Carinaria mediterranea* (Cambridge Natural History). 1, sucker; 2, fin; 3, shell; 4, gill; 5, tentacle. Fig. 866—*Atlanta peroni* (Leunis). Fig. 867—*Eulima oleacea* (Verrill).

CARINARIA Lamarck. Small conical shell present: 8 species in tropical and subtropical seas; 1 species on the South Atlantic coast.

C. mediterranea Péron and Lesueur (Fig. 865). Body 20 cm. long or less; snout violet; foot red: New Jersey to Florida; West Indies; Mediterranean Sea.

FAMILY 2. ATLANTIDAE.

Shell spiral and discoid and large enough to receive the entire body: 22 species, in 2 genera.

1. ATLANTA Lesueur. Shell small, thin, compressed, with a prominent keel on the periphery; aperture narrow, with a deep notch at the keel; operculum ovate: 18 species, 6 on the South Atlantic coast.

A. peroni Les. (Fig. 866). Length 8 cm.: New Jersey to Texas; West Indies; Mediterranean.

2. Oxygyrus Benson. Shell milky white, rounded on the periphery and keeled only near the aperture, which has no notch: 4 species, 1 on the South Atlantic coast.

O. keraudreni D'Orbigny. New Jersey to Texas; West Indies.

Division 3. GYMNOGLOSSA.

Similar to the *Tænioglossa* except that the radula and jaws are absent: 2 families, both marine.

Key to the families of *Gymnoglossa:*

a_1 Apical whorls normal; animals often parasitic.....1. Eulimidae
a_2 Apical whorls sinistral.....2. Pyramidellidae

Family 1. EULIMIDAE.

Shell usually elongate, conical, and multispiral, white in color and polished; foot long and narrow; proboscis very long, sometimes longer than the body; animal often parasitic, sucking the juices of its host by means of the long proboscis: 5 genera and numerous species.

1. Eulima Risso. Shell slender, tall, sometimes bent; operculum horny, spiral: 50 species, mostly southern, many parasitic.

E. oleacea Kurtz and Stimpson (Fig. 867). Shell small, solid, with 12 flattened whorls; color pale brown; aperture small, oval; length 6 mm.; width 1.5 mm.: Vineyard Sound to North Carolina; parasitic on *Thyone briareus.*

2. Stylifer Broderip. Shell thin, transparent, ovate or elongate, with a very sharp apex which is sometimes bent; operculum wanting; aperture small; tentacles slender; eyes sessile: 20 species; cosmopolitan; parasitic on or in the integument of echinoderms, often producing tumors.

S. stimpsoni Verrill. Shell white, swollen, with 4 to 5 whorls, the lowest very large, with an impressed revolving line just below the suture; length 3.75 mm.: Massachusetts to New Jersey; on *Strongylocentrotus.*

Family 2. PYRAMIDELLIDAE.

Shell conical, elongate or ovate, usually small, with apical whorls sinistral and excentric; operculum horny, spiral; tentacles ear-shaped, joined at the base; eyes sessile: several hundred species.

Key to the genera of *Pyramidellidae* here described:

a_1 Columella without a fold.....1. Turbonilla
a_2 Columella with an oblique fold.....2. Odostomia

1. Turbonilla Risso. Shell long and slender and multispiral, white or yellow, ribbed or striate; lip incomplete: 50 species; cosmopolitan.

T. elegans Verrill (Fig. 868). Whorls rounded, with numerous longitudinal ribs and fine revolving grooves; color light yellow; length 9 mm.; width 2.5 mm: Massachusetts Bay to Florida, in shallow water.

Fig. 868 *Turbonilla elegans* (Verrill).

T. interrupta (Totten). Shell very slender and pointed, with 8 or 10 convex whorls, on which are 20 to 30 ribs crossed by about 14 revolving lines: Cape Cod to South Carolina, in shallow water; common.

2. **Odostomia** Fleming. Shell minute, elongate, conical, thin; aperture ovate; columella with an oblique fold: 100 species; cosmopolitan.

Key to the species of *Odostomia* here described:

a_1 Surface smooth.
b_1 Color dark brown.....O. FUSCA
b_2 Color glossy white.....O. TRIFIDA
b_3 Color greenish with a line under the suture.....O. BISUTURALIS
a_2 Surface granulated.....O. SEMINUDA

O. bisuturalis (Say). Shell conical, smooth, light green; periostracum brown, with a single revolving line below the suture; length 5 mm.; diameter 2.5 mm.; 6 whorls: Massachusetts Bay to New Jersey; common under stones.

O. fusca (Adams). Shell elongate, rather blunt, dark brown, glossy, with 6 or 8 whorls; 6 mm. long; 1.8 wide; umbilical indentation present: Cape Cod to New Jersey, in shallow water; common.

O. trifida (Totten). Shell elongate; apex acute; whorls 8, flat, with about 6 revolving lines; color white; length 5 mm.; width 2 mm.: Massachusetts Bay to New Jersey, in shallow water; common.

Fig. 869 *Odostomia seminuda* (Verrill).

O. seminuda (Adams) (Fig. 869). Shell with an acute apex, 6 or 7 whorls, with coarse revolving lines crossed by longitudinal ones, giving the surface a granulated appearance; color glossy white; length 4 mm.; width 2 mm.: Massachusetts Bay to west Florida; common in shallow water.

Division 4. RACHIGLOSSA.

Radula long and narrow, with 3 longitudinal rows of teeth (Fig. 870), a central and two lateral, each tooth, in most species, consisting of a base and several cusps; proboscis long and retractile; siphon distinct and usually long; operculum usually present, and always horny and non-spiral; shell spiral, usually thick, often with tubercles or spines; aperture elongate, prolonged below to form a siphonal canal: 12 families, marine (excepting a few species); carnivorous.

Key to the families of *Rachiglossa* here described:

a_1 Shell rough, with ridges, tubercles, or spines.
  b_1 Central teeth without cusps.....2. COLUMBELLIDAE
  b_2 Central teeth with cusps.
    c_1 Laterals without cusps.....1. MURICIDAE
    c_2 Laterals with 2 or 3 cusps.
      d_1 Centrals with many cusps.....3. NASSIDAE
      d_2 Centrals with 5 to 7 cusps.....4. BUCCINIDAE
      d_3 Centrals with 2 cusps.....5. TURBINELLIDAE
a_2 Shell smooth and polished.
  b_1 Shell with a tall spire.....6. MITRIDAE
  b_2 Shell with a low spire.....7. OLIVIDAE

FAMILY 1. MURICIDAE.

Shell thick and solid, with an elevated spire with a rough surface on which are usually rows of protuberances or spines; siphonal canal often long; eyes sessile, at the outer base of the tentacles; central tooth of radula with at least 3 long cusps (Fig. 870, 1); laterals without any: about 15 genera and 1,000 species, which are mostly tropical; they feed largely on other mollusks, the shells of which they are able to pierce with the radula in the proboscis.

Fig. 870—Radula of Murex (Cambridge Natural History). 1, central; 2, lateral.

Key to the genera of *Muricidae* here described:

a_1 Whorls angular, with distinct protuberances or spines.
  b_1 Spines and protuberances usually very prominent.....1. MUREX
  b_2 About 10 longitudinal ridges.....3. EUPLEURA
a_2 Whorls rounded.
  b_1 Longitudinal ridges very distinct.....2. UROSALPINX
  b_2 Revolving ridges very distinct.....4. PURPURA

1. MUREX L. Spiny rock-shell. Shell thick, ovate or elongated; spire prominent; 3 or more rows of prominent protuberances or spines; aperture round, ending below in a long canal: about 300 species, in tropical and temperate seas. It was largely from *M. trunculus* L. and *M. brandaris* L. that the well known Tyrean or imperial purple dye of the ancients was obtained, a large mucous gland in the mantle furnishing a yellowish secretion which turns purple on exposure to the light. The secretion was obtained by crushing the animals, and large heaps of the broken shells of these two species may now be found where ancient manufactories of the dye existed, *M. trunculus* being found principally on the Syrian coast and *M. brandaris* in Greece and Italy.

M. festivus Hinds. Length 5 cm.; width 2.5 cm.; color white; canal closed: Californian coast, towards the south.

M. pomum Gmelin (Fig. 871). Length 12 cm.; color yellowish-brown; surface rough; aperture round and yellow in color, the outer lip having 3 brown spots: Beaufort, N. C., and southwards; West Indies; common.

Fig. 871
Murex pomum (Rogers).
1, siphonal canal.

2. **Urosalpinx** Stimpson. Shell fusiform, surface roughened by about 12 rounded, longitudinal ridges; lip scalloped; aperture with a short canal: 20 species.

E. cinereus (Say). Oyster drill (Fig. 872). Shell 25 mm. long, 15 mm. wide, brown or gray in color, brownish within; whorls 5 or 6, with numerous revolving lines which cross the longitudinal ridges: Florida to Massachusetts Bay, and locally further north, also at San Francisco; very common on oyster beds, being one of the worst enemies of the oyster, which it kills by drilling a small round hole through the shell, through which it thrusts its long proboscis.

3. **Eupleura** Adams. Shell fusiform; surface roughened by about 10 longitudinal ridges; whorls 7 and angulated, there being a shoulder beneath the suture: 5 species.

E. caudata (Say) (Fig. 873). Shell 25 mm. long, 15 mm. wide, brown or gray in color; aperture oval, with a long straight canal; lip

Fig. 872

Fig. 873

Fig. 874

Fig. 872—*Urosalpinx cinereus* (Verrill). 1, siphonal canal. Fig. 873—*Eupleura caudata* (Verrill). Fig. 874—*Purpura lapillus* (Verrill).

thick, roughened within: Cape Cod to west Florida, in shallow water; rather common.

4. **Purpura** Bruguière. Shell oval, lowest whorl large, with a large aperture, the canal being reduced to a notch at its lower end; columella flattened; outer lip simple: 60 species; cosmopolitan; several species.

P. lapillus (L.) (Fig. 874). Shell thick, with 5 or 6 whorls; spire acute; whorls with deep revolving furrows; lip arched, with ridges

within the margin; color whitish, yellowish, or reddish, often banded; length 30 mm.; width 17 mm.: eastern end of Long Island to Greenland, in shallow water on rocks; common, feeding on oysters and other mollusks; Europe.

Family 2. COLUMBELLIDAE.

Shell conical, elongate, covered by a periostracum; aperture narrow, elongated, terminating below in a notch; lip thick, crenulated or toothed within; operculum very small; central tooth of radula without cusps; laterals with 2 or 3 cusps: 1 genus.

Fig. 875 *Columbella lunata* (Verrill).

Columbella Lamarck. With the characters of the family: 300 species, mostly subtropical.

C. (*Astyris* Adams) **lunata** (Say) (Fig. 875). Shell small, with 6 whorls; surface rather flat, smooth, with a single revolving line and a few near the base; color brownish, with 2 or 3 series of crescentic yellow spots on the lower whorl; length 5 mm.; width 2.5 mm.: Massachusetts Bay to Florida, in shallow water; common.

C. (*Anachis* Adams) **avara** Say. Shell small, with 6 whorls; surface rather flat, yellowish in color, blotched with brown; lowest whorl with 10 to 15 longitudinal ridges crossed by revolving lines; length 12 mm.; width 5.5 mm.: Cape Cod to Florida, in shallow water; not so common as *C. lunata.*

Family 3. NASSIDAE.

Mud snails. Shell small, conical or ovate, with an elevated spire, thick and solid; aperture round or oval, ending below with a short canal or a notch; columella with a callus; outer lip thickened, toothed or crenate; operculum horny; central teeth of radula with many cusps; laterals with 2 large and several small ones: 175 species.

Fig. 876 Fig. 877

Fig. 876—*Nassa vibex* (Verrill). Fig. 877—*Nassa obsoleta* (Verrill).

Nassa Lamarck. Foot square in front, bifurcate behind or not; operculum with a serrate or plain margin: 130 species; cosmopolitan; in shallow water; they are scavengers, but are also predacious, destroying mollusks after the manner of the oyster drill.

N. vibex Say (Fig. 876). Shell conical, with 6 whorls; sutures not impressed; surface of body whorl with about 12 undulating, longitudinal ridges and 12 revolving lines; color whitish or brown, with a revolving darker band; foot bifurcate behind; length 12 mm.; diameter 8 mm.: Cape Cod to Gulf of Mexico; common south of Cape Hatteras; West Indies.

N. (*Tritia* Risso) **trivittata** Say. Shell conical, with 7 whorls; sutures impressed, with a shoulder below; surface with numerous longitudinal and revolving creases dividing it into series of large granules; foot bifurcate behind; color greenish-white, often with brown revolving bands, white within; length 18 mm.; width 8 mm.: Florida to Gulf of St. Lawrence; common.

N. (*Ilyanassa* Stimpson) **obsoleta** Say (Fig. 877). Shell conical, with 6 whorls, the lower one being large; surface covered with numerous longitudinal and revolving creases, giving it a reticular appearance; foot not bifurcate behind; margin of operculum not serrate; color brown, purple or black within; length 25 mm.; width 12 mm.: Gulf of St. Lawrence to west Florida; the commonest snail south of Cape Cod.

Family 4. BUCCINIDAE.

Shell usually thick and ovate or pear-shaped, with a conical spire and a large lower whorl; aperture usually large, ending below in a wide notch or a short, wide siphonal canal; central tooth of radula with 5 to 7 cusps; laterals with 2 or 3: over 1,100 species.

Key to the species of *Buccinidae* here described:

a_1 No distinct canal.....1. Buccinum
a_2 Distinct canal.....2. Neptunea

1. Buccinum L. Whelks. Shell covered with a horny periostracum; aperture with a wide notch at the lower side and about as long as the spire: 30 species, in colder waters.

B. undatum L. Shell with 6 whorls and grayish in color, with about 12 prominent crescentic or oblique longitudinal ridges, which disappear towards the tip and are crossed by numerous raised revolving lines; aperture oval, usually yellow, but sometimes white within; length 60 mm.; width 35 mm.: New Jersey to Greenland, from low to deep water; common north of Cape Cod; Europe, where it grows larger than here, and is a common article of food, and is also used extensively as bait for cod.

Fig. 878 *Neptunea pygmæa* (Verrill).

2. **Neptunea** Bolton (*Chrysodomus* Swainson). Shell fusiform, covered with a horny periostracum; spire elevated; aperture oval, shorter than the spire, with a short canal, white or yellowish in color: circumpolar, about 15 species on the Atlantic coast, mostly in deep water.

N. pygmæa (Gould) (Fig. 878). Shell with an elevated spire, with 6 whorls and a small, elongate aperture, ending below in a rather long canal; periostracum hirsute; length 20 mm.: Long Island Sound to the Gulf of St. Lawrence, in 10 to 640 fathoms.

N. decemcostata (Say). Shell with 6 whorls, with 10 rounded revolving ridges on the lower whorl and 2 on the upper; color white; ridges horn-colored; length 75 mm.; width 45 mm.: Cape Cod and northwards, in rather deep water, often thrown up on the beach.

Family 5. TURBINELLIDAE.

Shell fusiform or pear-shaped; aperture elongate, with a long siphonal canal; central tooth of radula with 3, laterals with 2 cusps: about 8 species on the Atlantic coast.

1. Busycon Bolton (*Fulgur* Montfort). Conchs. Shell large, with a short spire and a very large lower whorl, which tapers below into a long twisted canal; aperture large; outer lip thin and smooth; whorls 6: 5 species on the eastern coast of the United States; egg capsules lens-shaped, about 25 mm. wide, attached in a row to a common chord (Fig. 879).

Fig. 879—Egg capsules of *Busycon canaliculatum* (Rogers).

Key to the species of *Busycon* here described:

a_1 No sutural canal.
  b_1 Shell dextral.....B. CARICA
  b_2 Shell sinistral.....B. PERVERSUM
a_2 Revolving canal at suture.....B. CANALICULATUM

Fig. 880—*Busycon canaliculatum* (Rogers). 1, siphonal canal.

B. carica (L.). Shell thick, solid; spire conical, with a flattened surface and a revolving series of prominent tubercles above the suture; length 22 cm.; width 11 cm.; color gray or brownish: Cape Cod to the Gulf of Mexico, in shallow water; common, especially towards the south; the largest shell on the coast except *Strombus gigas*.

B. canaliculatum (L.) (Fig. 880). Shell thin, covered with a hirsute periostracum, and with a deep, broad canal at the suture; length 13 cm.; color brownish, with numerous revolving lines: Cape Cod to Gulf of Mexico, in shallow water; very common.

B. perversum (L.). Shell similar to *B. carica,* but sinistral: Cape Hatteras to Texas; West Indies.

Family 6. MITRIDAE.

Shell smooth and polished, elongate, conical, with a high spire and a small, narrow aperture; columella with folds: several hundred species, in tropical seas.

Mitra Lamarck. Shell thick; outer lip thick and smooth within: 200 species, including many beautiful shells which are used as ornaments.

M. papalis (L.). Papal mitre. Length 13 cm.; a revolving row of tooth-like folds on the suture; color white, with irregular red spots: Indian Ocean; often used as ornaments.

M. swainsoni Broderip (Fig. 881). Length 8 cm.; surface with numerous fine revolving stripes: North Carolina and southwards.

Family 7. OLIVIDAE.

Shell brightly colored and polished and elongate, with a short spire sometimes more or less covered by a callous deposit, and a very large lower whorl which makes up the greater part of the shell; aperture long and narrow; operculum often wanting: about 250 species, mostly subtropical.

Fig. 881

Fig. 882

Fig. 881—*Mitra swainsoni* (Dall). Fig. 882—*Oliva litterata* (Rogers).

1. Oliva Bruguière. Shell almost cylindrical; columella with folds; no operculum; foot large, partly enveloping the shell: 150 species.

O. litterata Lamarck (Fig. 882). Shell slender, tapering towards both ends, 6 cm. long, whitish in color, with spiral bands of brown markings; aperture lined with violet: North Carolina to Key West; West Indies; on sandy beaches.

2. Olivella Swainson. Shell small; spire taller than in *Oliva;* suture caniculated; operculum present; tentacles and eyes absent: 31 species.

O. mutica (Say). Rice shell (Fig. 883). Shell fusiform, 12 mm. long; color whitish, with wavy brown bands on the lower whorl; aperture half the length of the shell: North Carolina to Florida; West Indies; on sandy beaches.

Fig. 883 *Olivella mutica* (Rogers).

3. Harpa Lamarck. Harp shell. Shell large, with a large, bulging lower whorl and with prominent longitudinal ribs; foot large; radula absent in the adult; aperture large; no operculum: 9 species, in tropical seas, but not in the Atlantic.

H. ventricosa Lam. (Fig. 884). Length 12 cm.; color brownish, with square spots of purple forming broad spiral bands on the whorls; between the ribs are scallops of light and dark brown: Indian Ocean; often used as an ornament.

Fig. 884
Harpa ventricosa (Rogers).

Division 5. TOXOGLOSSA.

Radula long and narrow, with 2 rows of long teeth, which are the marginals, the centrals and laterals being absent; proboscis with a poison gland; siphon distinct; aperture either notched below or prolonged to form a siphonal canal; shell spiral: 4 families, all marine, and mostly carnivorous, the animals feeding largely on mollusks which they kill by means of their long teeth and the poison.

Key to the families of *Toxoglossa:*

a_1 Shell a reversed cone.....2. Conidae
a_2 Shell not a reversed cone.
  b_1 Shell with a tall spire.
    c_1 Aperture ending below with a notch.....1. Terebridae
    c_2 Aperture channelled below notched above.....3. Pleurotomidae
  b_2 Shell more or less ovate.....4. Cancellariidae

Family 1. TEREBRIDAE.

Shell elongate, with a very tall acute spire and with flattened whorls; aperture small, with a deep notch below; operculum horny; tentacles short, wide apart, with eyes at their tips or wanting: 1 genus.

Terebra Lamarck. With the characters of the family: 200 species, mostly tropical.

T. dislocata Say. Shell 44 mm. long, 8 mm. wide; color brownish or yellowish, with a pale revolving band and numerous minute revolving lines; whorls 13, with 15 to 18 ribs on each and numerous minute revolving grooves: Maryland to Texas and in the West Indies; in shallow water.

Family 2. CONIDAE.

Shell thick, conical, with a low, flattened spire and a very large lower whorl which tapers towards the lower end; surface often smooth and brightly colored; aperture long and narrow; operculum present or absent; proboscis long; siphon short and thick: numerous species, mostly tropical, many very beautiful.

Conus L. With the characters of the family: 300 species.

C. californicus Hinds. Spire without protuberances; color of shell white, of periostracum chestnut; latter sometimes hirsute; length 25 mm.: California, towards the south.

C. floridanus Gabb. Spire rather high; color yellowish, streaked with broken lines of brown spots; length 5 cm.: Cape Hatteras to Florida.

C. marmoratus L. (Fig. 885). Spire low; color dark brown, with large triangular white spots; length 12 cm.: Indian and Pacific Oceans; common in collections.

Family 3. PLEUROTOMIDAE.

Shell elongate, with a tall spire; lower whorl prolonged to form a long canal; aperture narrow and long; outer lip thin, with a notch near

Fig. 885

Fig. 886

Fig. 887

Fig. 885—*Conus marmoratus* (Rogers). Fig. 886—*Bela harpularia* (Verrill). Fig. 887—*Cancellaria reticulata* (Rogers).

the upper end; operculum horny, sometimes absent; eyes at the base of the tentacles; siphon long: 650 species; cosmopolitan; mostly in deep water and towards the south.

Bela Leach. Shell fusiform and thin; canal short; notch of outer lip small or wanting; operculum pointed at both ends; aperture short: northerly in distribution.

B. harpularia (Couthouy) (Fig. 886). Shell with 6 or 8 whorls, which have a shoulder just beneath the suture; brownish-pink in color and with rounded longitudinal ribs which are crossed by fine revolving lines; length 16 mm.; width 8 mm.: Long Island Sound to Nova Scotia, in rather deep water.

Family 4. CANCELLARIIDAE.

Shell ovate or elongate, with longitudinal and revolving ridges and grooves; aperture elongate, prolonged below to form a siphonal canal; columella with spiral folds; outer lip ribbed within; no operculum: 80 species.

Cancellaria Lamarck. Shell cancellated, reticulated or ribbed; columella with prominent folds; canal rather short; outer lip bulging: 70 species, in warm seas.

C. reticulata (L.) (Fig. 887). Shell 5.5 cm. long and banded with yellow, white, and brown: Cape Hatteras to west Florida, in shallow water.

Class 4. **PELECYPODA.*** (Lamellibranchiata.)

Symmetrical mollusks with a double or bivalve shell and mantle, and without a head (Fig. 740, C).

External Structure.—The compact visceral mass is compressed laterally and the two lobes of the mantle extending downwards from the back entirely enclose both it and the foot. When the animal moves about the foot is extended between the edges of the mantle (Fig. 888, 1). The hinder part of the mantle lobes controls the inflow and the outflow of water between the mantle cavity and the outside. In some of the more primitive bivalves, especially such as are sessile, as the oyster, this function is but little localized, a current flowing out of the mantle cavity in the region of the anus and one flowing into it at other portions of its hinder and lower borders (Fig. 888). In most bivalves, however, the hinder margins of the mantle are highly modified, and are closely applied to each other, leaving two openings which are called siphons; through the lowermost of these, which is called the branchial or incurrent siphon, water flows into the mantle cavity, bringing the microscopic food of the animal and the air needed for respiration, and through the uppermost, which is called the cloacal or excurrent siphon, it flows out, conveying the exhausted respiratory water with the excrement and often the genital products. In very many pelecypods the posterior mantle edges forming the siphons are not merely applied to each other but are fused together and extended in the form of tubes. Fusion has also taken place to a greater or less extent along the entire edge of the mantle in the higher bivalves, a small slit only being left for the foot (Fig. 888).

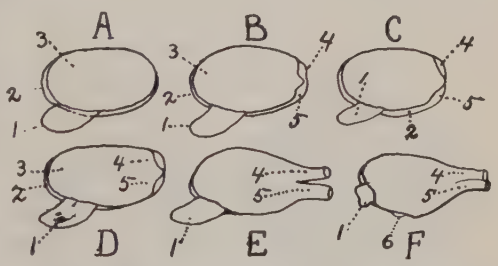

Fig. 888—Diagrams showing the formation of the siphons, the anterior end in each figure being towards the left and the dorsal side being above. A, mantle open and no definite siphons; B, mantle open and incomplete siphons; C, cloacal siphon complete; D, both siphons complete but not extended; E, siphons extended and mantles joined ventrally; F, mantles completely joined, leaving a narrow space for the foot and one for the byssus (Lang). 1, foot; 2, left-hand mantle; 3, right-hand mantle; 4, cloacal siphon; 5, branchial siphon; 6, byssus opening.

* See "The Mollusca of the Chicago Area; The Pelecypoda," by F. C. Baker, The Natural History Survey, Bull. No. III, Pt. 1, 1898.

The shell, like the mantle, consists of two parts or valves, which are joined together dorsally and open ventrally to permit the edges of the mantle, the siphons, and the foot to be protruded. The shell is invariably present, but may be rudimentary; the two valves are not always symmetrical, and vary much in thickness in the different species. The outer layer or periostracum is thin and non-calcareous and is often wanting. The inner or mother-of-pearl layer shows a play of colors in many species, due to the refraction of light by the delicate horizontal plates of which it is composed, which often gives the shell commercial value. Pearls are cysts of mother of pearl which have formed around foreign objects, usually larval trematode worms, which have lodged between the mantle and the shell. The middle or columnar layer is usually thick. The mother-of-pearl layer is deposited by the general surface of the mantle. The other two layers are formed by its margin, and hence show concentric lines of growth. These lines are grouped around the umbo or beak at the dorsal margin of the shell, which is the oldest part of it, and often prominent, and often projects forwards. In front of it is, in certain bivalves, a heart-shaped depressed area called the lunule (Fig. 889, 4). The two valves of the shell are held together by a more or less elastic band called the ligament (2), which is usually external and consists of two distinct parts, the outer portion or ligament proper and the internal portion or cartilage, the latter being very elastic and composed of parallel fibers.

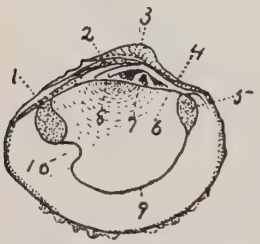

Fig. 889—Left-hand valve of shell, the anterior end being toward the right, and the dorsal side above (Cambridge Natural History). 1, posterior adductor muscle impression; 2, ligament; 3, umbo; 4, lunule; 5, anterior adductor muscle impression; 6, anterior lateral teeth; 7, cardinal teeth; 8, posterior lateral teeth; 9, pallial line; 10, pallial sinus.

Beneath the umbo is the hinge, which is usually composed of interlocking teeth in the two valves. These teeth are distinguished as cardinals and laterals, the former (7) being immediately beneath the umbo; the latter often consist of long ridges and are called the posterior laterals (8) when they are behind, and the anterior laterals (6) when in front of the umbo. The inner surface of each valve shows, often prominently, a number of impressions caused by the attachment of muscles in the shell. These are the adductor muscle impressions (1 and 5), of which there are either one or two, the much smaller impressions of the siphonal and pedal retractor muscles, and the pallial line (9). The latter is a broad line which connects the anterior and posterior adductor impressions and represents the points where the numerous retractor muscles of the margin of the mantle are inserted; it is often indistinct.

The siphonal muscle impression is present only in shells possessing elongated, retractile siphons, and is situated beneath or behind the posterior adductor impression, where it forms a more or less prominent forward bend or angle in the pallial line, which is called the pallial sinus (10).

The two valves of the shell are closed by the two powerful adductor muscles above mentioned, which are attached to their inner surface; in a large number of pelecypods but one muscle is present, the anterior adductor being wanting. When the adductors are relaxed the elasticity of the hinge ligament causes the shell to open. Other muscles which are attached to the shell extend the foot and the siphons.

The mantle cavity contains the ctenidia or gills, which are usually plate-like structures attached along their dorsal margins, two gills lying usually on each side (Fig. 890, C). In the simplest pelecypods (Fig. 890, A), however, a pair of bipinnate ctenidia similar to those of gastropods is present. At the forward end of the visceral mass in the median line is the mouth (Fig. 740, C). It is without jaws or radula, and on each side of it are two ciliated flaps called oral palps (Fig. 904), the cilia of which cause small food particles, more or less immersed in mucus, to pass into the mouth. The anus is at the hinder end and opens into the dorsal or cloacal portion of the mantle cavity. The foot is wanting in some pelecypods, but in most of them it is a wedge or tongue-shaped structure; the most primitive forms have a disc-like sole like the gastropods. Very many pelecypods secrete a tough, stringy substance from a gland in the foot called the byssus (Fig. 898, 5), by means of which they attach themselves to stationary objects, becoming thus fixed in one place. In many forms which are without it as adults, the byssus is present in the larva. Many bivalves attach themselves permanently by cementing one of the valves to some other object or by boring cavities into clay, rock, or wood, from which they cannot escape.

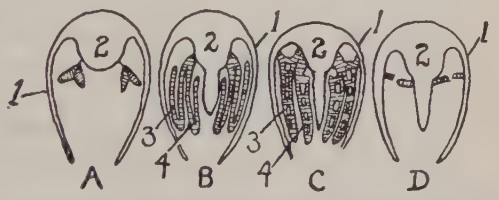

Fig. 890—Diagrams of pelecypod gills. A, *Protobranchiata;* B, *Filibranchiata;* C, *Eulamellibranchiata;* D, *Septibranchiata* (Lang). 1, mantle; 2, visceral mass; 3, ascending lamella of gill; 4, descending lamella of gill.

Internal Structure (Fig. 904).—The mouth is without salivary glands and is joined by a short œsophagus with the large stomach. Surrounding this organ is the voluminous liver. The intestine (Fig. 740, C) is a long tube which winds about in the visceral mass, to the dorsal side of which it finally ascends, where it passes backwards through the ventricle of the heart (except in the oyster, and certain others) to the anus. At

the forward end of the intestine is usually a tubular pocket, which opens into the stomach in some forms, containing a crystalline rod of unknown function. The heart consists of a muscular ventricle and a pair of auricles which receive the blood which has just passed through the gills. The kidneys are paired, each opening into the pericardium and also into the mantle cavity. Additional excretory glands are the organs of Keber, which are a pair of glandular organs arising either from the walls of the auricle or the pericardium; they are wanting in the *Protobranchiata*. Three pairs of widely separated nerve ganglia characterize most bivalves, the cerebral ganglia, just above the mouth, the pedal ganglia in the foot, and the visceral ganglia at the hinder end of the visceral mass; the cerebral ganglia are joined with each of the other pair by a pair of connectives.

In correlation with their sluggish habits, the special sense organs of the bivalves are poorly developed. A pair of osphradia, which are supposed to be olfactory organs, are present at the base of the gills near the posterior adductor muscle. Tactile cells are often present, especially upon the siphons and the edge of the mantle. Eyes are usually absent but are present in a number of forms. *Pecten* possesses highly developed eyes, which are on projections at the edge of the mantle. *Arca* has compound eyes, similar to those of arthropods. A pair of lithocysts occurs in the foot.

The gonads are branched organs which open into the mantle cavity at the base of the gills. In the *Protobranchiata* and certain other primitive forms the gonads open into the kidneys, but in most bivalves distinct genital ducts are present. The sexes are usually separate, but hermaphroditism is not uncommon. Ova and sperm are extruded into the water, where fertilization takes place. Special egg capsules are not formed; in the *Unionidae*, however, the eggs are taken into the water tubes usually of the outer and in the *Cyrenidae* into those of the inner gills, where they are protected until they hatch.

Distribution and Habits.—Pelecypods are all aquatic, and mostly marine animals which live in great part in shallow water along the margins of the continents. They vary in size between the gigantic *Tridacna gigas* of the Pacific Ocean, the shells of which may be a meter and more long and weigh 250 kilograms, and the minute fresh water *Pisidium* or *Sphærium*, which may measure only a few millimeters in length. Most of them creep slowly about on the wedge-shaped foot, some can spring (*Cardium*), while some move by squirting water from the siphons (*Ensis*). *Pecten* swims rapidly by clapping the shells together. The food consists of minute animals and plants, which are drawn into the mouth by the cilia of the oral palps. Very many bury themselves in

the sand or mud or bore into clay, wood, or rock, with only the tips of the siphons extending into the water, and are then protected from their enemies. Others protect themselves from predacious fish by fastening themselves to some other object by means of their byssus, or cementing the shell to a rock or stone.

Bivalves are useful to man in a variety of ways. Many are important articles of food, the oyster and clam being raised artificially for this purpose. The shells of numerous species, especially the large fresh-water mussels, are used for making buttons and other things, and pearls are probably the most valuable single objects obtained from any animal whatsoever.

History.—The term bivalve was employed by Linnæus, in whose system of classification the *Bivalvia* were a subdivision of the *Testacea,* one of the four divisions of *Vermes.* Cuvier called the group the *Acephala,* and included in it, besides the bivalves, tunicates, brachiopods, and cirripeds. Blainville named bivalves the *Lamellibranchiata* (1816), a name which has had the greatest vogue of any of the numerous names given to this group, down almost to the present time. In 1818 Lamarck called them the *Conchifera,* and in 1821 Goldfuss, the *Pelecypoda.* The latter name was revived by Tryon (1884) and Fischer (1885), and has in the past few years almost entirely supplanted the others.

The main subdivisions of the class, in the older books, were usually based upon the presence and form of the siphons or the adductor muscles, but at the present time the system proposed by Pelseneer (1888), the basis of which is the structure of the gills, is universally adopted.

The *Pelecypoda* contain about 11,000 species grouped in 5 orders, of which a fifth inhabit fresh water; about 15,000 fossil species are known.

Key to the orders of *Pelecypoda:*

a_1 Gills not lamellar but pinnate (Fig. 890, A), and in the hinder part of the mantle cavity; foot with a creeping surface; pallial sinus present or absent (Fig. 889, 10) ..... 1. PROTOBRANCHIATA

a_2 Gills composed of rows of parallel filaments (Fig. 890, B); no pallial sinus; byssus well developed ..... 2. FILIBRANCHIATA

a_3 Gill filaments joined together; no pallial sinus; but one muscle. 3. PSEUDOLAMELLIBRANCHIATA

a_4 Gill filaments completely joined, forming a continuous surface (Fig. 890, C); pallial sinus usually present (Fig. 889, 10); most pelecypods ..... 4. EULAMELLIBRANCHIATA

a_5 Gills absent; pallial sinus present ..... 5. SEPTIBRANCHIATA

ORDER 1. PROTOBRANCHIATA.

Gills (Fig. 890, A) consisting on each side of an axis, to which are attached 2 rows of short, flat leaflets projecting backwards freely into the mantle cavity; foot more or less of a flat creeping sole often surrounded

by a fringed margin; gonads open into the kidneys; 2 adductor muscles; mantle either open below or closed; siphons either absent or present: 2 families, both marine.

Key to the families of *Protobranchiata:*

a_1 Hinge with teeth.....1. NUCULIDAE
a_2 Hinge toothless.....2. SOLEMYIDAE

FAMILY 1. NUCULIDAE.

Shell equivalve, oval or triangular, pearly within; hinge with great numbers of saw-like teeth, interrupted by a central pit for the ligament, which is either external or internal; mantle open below; no byssus; oral palps very large, with a posterior appendage: about 40 species on the Atlantic coast, mostly in deep water.

Key to the genera of *Nuculidae* here described:

a_1 No siphons; hinder part of the shell not prolonged and without pallial sinus.....1. NUCULA
a_2 Siphons and pallial sinus present; hinder part of shell prolonged.
b_1 Pallial sinus large.....2. YOLDIA
b_2 Pallial sinus small.....3. LEDA

Fig. 891

Fig. 892

Fig. 891—*Nucula proxima* (Verrill). Fig. 892—*Nucula delphinodonta* (Verrill).

1. NUCULA Lamarck. Shell oval, somewhat triangular, with a short posterior side; periostracum olive; foot used for burrowing: 70 species, cosmopolitan.

N. proxima (Say) (Fig. 891). Shell strongly oblique, thick; umbo prominent; hinge teeth large, 12 behind and 18 before the umbo, the two series of teeth forming nearly a right angle; length 10 mm.; height 9 mm.; width 6 mm.: South Carolina to Gulf of St. Lawrence; often common in shallow water.

N. delphinodonta* Mighels (Fig. 892). Shell ovate, somewhat oblique; hinge teeth, 3 behind and 7 before the umbo; length 3.2 mm., height 2.7 mm.; width 2.2 mm.: New Jersey to Greenland, in 6 to 100 fathoms; often abundant; Europe.

2. YOLDIA Möller. Shell elongate, compressed, smooth, and shining, attenuated and gaping behind, dark olive in color; mantle open, with elongated, united, retractile siphons; animal very active, leaping through the water: about 12 species on the Atlantic coast.

Y. limatula† (Say) (Fig. 893). Shell 48 mm. long, 23 mm. high, and 13 mm. wide; umbo near the center, the posterior dorsal slope

* See "Life History of Nucula delphinodonta," by G. A. Drew, Quart. J. M. S., Vol. 44, New Ser., 1901.

† See "Yoldia limatula." by G. A. Drew, Mem. Biol. Lab., Johns Hopkins, Vol. 4, 1889.

straight; teeth prominent, 23 on anterior and 18 on posterior side: North Carolina to Labrador in shallow water; common; Pacific coast; Europe.

Y. sapotilla (Gould). Like the above but much smaller, and with about 16 teeth on each side; 22 mm. long, 11 mm. high and 7 mm. wide: Long Island to Arctic Ocean; often common, in 4 to 120 fathoms.

Y. thraciæformis Storer. Shell reniform, rounded and broadest behind, gaping at both ends; 5 cm. long; 4 cm. high, and 27 mm. wide; hinge with about 12 teeth on each side: Long Island to Arctic Ocean; in rather deep water.

3. **Leda** Schumacher. Shell elongated, the hinder part being much prolonged; mantle open, with small, united siphons: 80 species, cosmopolitan.

L. tenuisulcata (Couthouy) (Fig. 894). Shell 25 mm. long, 12 mm. high, and 7.5 mm. wide, light greenish-yellow in color, with 12 anterior

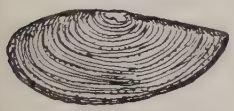

Fig. 893

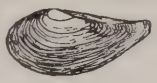

Fig. 894

Fig. 895

Fig. 893—*Yoldia limatula* (Verrill). Fig. 894—*Leda tenuisulcata* (Gould). Fig. 895—*Solemya velum* (Verrill).

and 16 posterior teeth: Rhode Island northwards, in shallow water; often common.

Family 2. SOLEMYIDAE.

Shell equivalve, elongate, cylindrical, gaping at each end; periostracum thick, extending over the edge of the shell; hinge toothless; foot long and slender; oral palps elongate; mantle fused below, leaving an opening for the foot and one hourglass-shaped siphonal opening behind: 1 genus.

Solemya* Lamarck (*Solenomya* Menke). With characters of the family: several species.

S. velum Say (Fig. 895). Shell very thin and fragile, yellowish-brown in color, with about 15 impressed lines radiating from the umbo to the margin, bluish-white within, 25 mm. long, 12 mm. high, and 8 mm. wide: North Carolina to Nova Scotia; usually buried in the sand; also found swimming backwards and forwards; often common.

S. borealis Totten. Like the above but much larger and darker; length 5 cm.; height 22 mm.; width 14 mm.: Long Island Sound to Nova Scotia; rare.

* See "Locomotion in Solenomya," etc., by G. A. Drew, Anat. Anz., Vol. 17, 1900.

Order 2. FILIBRANCHIATA.

Gills consisting on each side of an axis, to which are attached 2 rows of very long, filamentous leaflets (Fig. 890, B), which hang down far into the mantle cavity, each row being recurved and bent upwards, so that each leaflet has a descending and an ascending limb, which are not joined by interlamellar partitions, except in the *Mytilidae;* genital and kidney pores separate (except in the *Anomiidae*); foot usually weak, with well developed byssus; 2 adductor muscles; mantle open below; siphons absent or little developed: 4 families, all marine.

Key to the families of *Filibranchiata* here described:

a_1 Shell not equivalve, animal attached.....1. Anomiidae
a_2 Valves of shell alike.
b_1 Not attached by byssus.....2. Arcidae
b_2 Attached by byssus.....3. Mytilidae

Family 1. ANOMIIDAE.

Shell thin, with asymmetrical valves, the right valve being undermost and provided with a deep notch or a hole, through which a calcified byssus projects, fastening the animal to a rock or a shell; oral palps wanting; posterior adductor the larger; mantle fringed, with short cirri; no siphons; foot cylindrical, expanded and grooved at the end; sexes separate: 4 genera.

Fig. 896
Anomia ephippium (Verrill).
1, left valve; 2, right valve; 3, notch.

Anomia L. Right valve flat; left valve convex: 40 species.

A. ephippium L. (*A. simplex* D'Orbigny). Jingle shells (Fig. 896). Shell variable in shape, circular or oval in outline, about 25 mm. in diameter, or larger; outer surface scaly and dark colored, but in dead shells often worn off, exposing the glistening greenish or golden mother of pearl: Nova Scotia to Texas; West Indies; in shallow water, abundant on oyster beds; Europe, where it is used for food.

A. aculeata Gmelin. Shell 12 mm. in diameter, covered with scaly or prickly radiating lines on upper valve: Long Island to the Arctic Ocean; Europe; in shallow water; common north of Cape Cod.

Family 2. ARCIDAE.

Shell oval, symmetrical, with a heavy periostracum, and usually with the radial corrugations; hinge with a row of similar comb-like teeth; mantle open below; foot large, bent, and grooved; both adductors large; no siphons: several hundred species; cosmopolitan.

Arca L. Blood clams. Shell equivalve, or nearly so, thick; umbo anterior; foot pointed, with a byssus; edges of mantle with numerous compound eyes: 140 species.

A. noae L. Noah's arch. Shell elongated, wide, angular, almost quadrangular; umbo prominent, the two being far apart; valves gaping below, with radial ribs; length 10 cm.: Cape Hatteras, southwards, in shallow water; West Indies; Pacific coast; Mediterranean Sea.

A. pexata Say (Fig. 897). Shell thick, oblong, with prominent umbo directed very obliquely forwards, and with about 32 to 36 radiating ribs, 56 mm. long, 53 mm. high and 37 mm. wide; periostracum thick and shaggy and dark brown in color: Maine to Florida, often common on the bottom in shallow water, or attached by the byssus.

Fig. 897
Arca pexata (Gould).

A. transversa Say. Shell rhomboidal, the umbo not directed so obliquely forwards as in *A. pexata*, with 32 to 36 ribs; color brown; length 37 mm.; height 25 mm.; width 37 mm.: Cape Cod to Florida, in shallow water.

Family 3. MYTILIDAE.

Mussels. Shell elongate, equivalve, with umbo at or near anterior end; hinge usually toothless; foot cylindrical and grooved, with byssus; anterior adductor small, posterior large; distinct cloacal but no branchial siphon: several hundred species.

Key to the genera of *Mytilidae* here described:

a_1 Animals not boring.
  b_1 Umbo at extreme anterior end.....1. Mytilus
  b_2 Umbo not quite at anterior end.
    c_1 Length 25 mm. or over.
      d_1 Two striated areas not present.....2. Modiolus
      d_2 Two distinct striated areas.....3. Modiolaria
    c_2 12 mm. long.....4. Crenella
a_2 Boring animals.....5. Lithophagus

1. **Mytilus** L. Shell wedge-shaped, being pointed in front and round behind, smooth; umbo at anterior end: 65 species; cosmopolitan.

M. edulis L. (Fig. 898). Edible mussel. Color of periostracum black or dark brown, within pearly with violet margins; length 10 cm.; height 35 mm.; width 25 mm.: circumpolar, south to North Carolina and San Francisco; Europe; very common, attached to rocks and to each other; between tide lines and in shallow water; used for food in Europe.

2. **Modiolus** Lamarck. Horse mussels. Shell wedge-shaped, inflated in front; umbo not quite at front end: 70 species; cosmopolitan; the animals burrow in the sand and gravel, and differ in this respect from *Mytilus*.

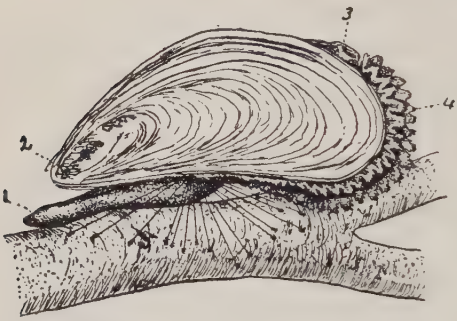

Fig. 898—*Mytilus edulis* (Lang). 1, foot; 2, umbo; 3, cloacal siphon; 4, mantle; 5, byssus.

M. modiolus (L.) (Fig. 899). Periostracum thick, coarse in texture, dark brown in color; interior pearly; length up to 15 cm., but usually under 4 cm.; usual height 2 cm.; width 45 mm.: circumpolar, south to New Jersey and San Francisco; Europe; common in deep water, among rocks and gravel.

M. demissus Dillwyn. Shell elongate; surface marked by numerous impressed radiating ribs; color greenish-yellow; pearly within, tinted with purple; length 75 mm.; height 30 mm.; width 23 mm.: Georgia to Nova Scotia; very common on mud flats; also at San Francisco.

3. **Modiolaria** Gray. Shell elliptical, front end blunt; surface with two areas of fine radial striations, one anterior and one posterior, between which there are no striations; cloacal siphon long: many species.

Fig. 899

Fig. 900

Fig. 899—*Modiola modiolus* (Verrill). Fig. 900—*Modiolaria nigra* (Verrill).

M. nigra (Gray) (Fig. 900). Shell 5 cm. long, 28 mm. high, and 15 mm. wide; brown in color; anterior striated area small in extent: circumpolar, south to Long Island, in shallow water; Europe.

M. discors (L.). Shell oval, 25 mm. long, 16 mm. high, 10 mm. wide, dark greenish in color; anterior area with 16 striations: circumpolar, south to Long Island and Puget Sound, from low water to 500 fathoms; common north of Cape Cod; Europe.

4. **Crenella** Brown. Shell small, oval or rhomboidal, with numerous radiating striations or ribs; hinge with a tooth in each valve; foot with a disc at end; byssus a single thread; umbo near anterior end: about 5 species on the Atlantic coast.

C. glandula (Totten) (Fig. 901). Shell 12 mm. long, 9 mm. high, 7 mm. wide, brownish-yellow in color: New Jersey to Gulf of St. Lawrence, in shallow water.

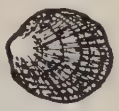

Fig. 901
Crenella glandula (Verrill).

5. Lithophagus Bolten (*Lithodomus* Cuvier). Shell cylindrical, inflated, rounded in front, wedge-shaped behind: 4 species on the South Atlantic and 1 on the Pacific coast.

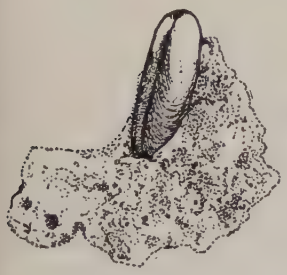

Fig. 902
Lithophagus lithophagus (Rogers).

L. lithophagus (L.) (Fig. 902). Shell elongate, 3 to 8 cm. long, with fine longitudinal and transverse lines: Florida; West Indies; Europe; it attaches itself to a rock by its byssus when young, into which it bores when adult, forming a hole the shape of the shell. It made the holes in the columns of the Temple of Serapis at Puzzuoli in Italy, which are used as proofs of the oscillations of the coast in that region.

Order 3. PSEUDOLAMELLIBRANCHIATA.

The consecutive filamentous leaflets of each row of the gills are more or less connected, and the two limbs of each leaflet are joined by interfilamentary partitions (Fig. 890, C); the ascending limb also of the outer leaflet is united with the mantle, except in *Pectinidae;* foot weak or absent; genital and kidney pores distinct except in the *Pectinidae;* but 1 adductor muscle, the anterior usually being very small or absent; mantle entirely open, with no siphons: 4 families, all marine.

Key to the families of *Pseudolamellibranchiata* here described:

a_1 Two adductor muscles, the anterior one very small.....1. Aviculidae
a_2 But one adductor muscle.
b_1 Shell irregular; oysters.....2. Ostreidae
b_2 Shell regular; scallops.....3. Pectinidae

Family 1. AVICULIDAE.

Shell usually with valves of unequal size, the right valve being smaller; animal rests on the right valve and is attached by its byssus: numerous species, in tropical and temperate seas; about 6 species on the Atlantic coast, all towards the south. The pearl oyster, *Meleagrina margaritifera* (L.), which attains a length of 30 cm. and lives in the Indian Ocean in 6 to 15 fathoms, belongs to this family. A closely allied species of the same genus in the West Indian waters also furnishes pearls.

Pinna L. Shell equivalve, wedge-shaped, with the pointed end, on which is the umbo, anterior in position; posterior end broad and gaping; hinge teeth absent: 30 species, some of which produce black pearls of considerable value.

P. muricata L. (Fig. 903). Shell white and semitransparent, with straight sides with obscure longitudinal ribs, which are covered with scales; length 17 cm.: North Carolina to Texas.

Family 2. OSTREIDAE.

Oysters. Shell inequivalve, resting on and attached by the left valve, irregular and variable in shape, very thick, often in folded layers; foot absent: 1 genus.

Ostrea* L. Shell circular or elongate, upper valve more or less flat and the lower convex; umbo and hinge at forward end; hermaphroditic or unisexual; adductor muscle near the middle with the heart just in

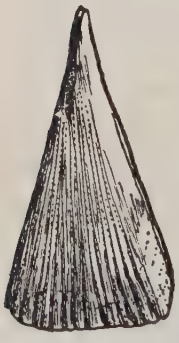

Fig. 903

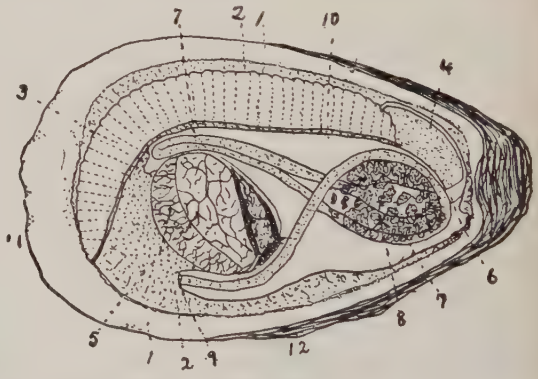

Fig. 904

Fig. 903—*Pinna muricata* (Rogers). Fig. 904—*Ostrea virginica*—left valve removed to show organs (Brooks). 1, right valve of shell; 2, mantle; 3, gills; 4, labial palps; 5, rectractor muscle; 6, mouth; 7, intestine; 8, stomach surrounded by the liver; 9, anus; 10, visceral mass; 11, posterior end of animal; 12, dorsal side of animal.

front of it; muscle impressive violet or brown; shell white: about 100 species, in all seas except the colder ones; 1 species on the Atlantic and 1 on the Pacific coast; 500 fossil species.

O. virginica Gmelin (Fig. 904). The American oyster. Length up to 45 cm., usually about 12 cm.: Gulf of Mexico to Massachusetts, locally to Gulf of St. Lawrence, in shallow and brackish water, often very abundant, the most valuable American invertebrate animal; introduced on the Pacific coast.

* See "The Oyster," by W. K. Brooks, 2nd Ed., 1905. "A Manual of Oyster Culture," by Caswell Grave, Fourth Rep. Maryl. Shellf. Com., 1912.

O. lurida Carpenter. The Pacific coast oyster. Diameter 5 cm. or less; shell thin and purplish: Puget Sound to California.

Family 3. PECTINIDAE.

Scallops. Shell inequivalve, either free or attached, with radial ribs or striations; foot cylindrical; without siphons: about 7 genera.

Pecten O. F. Müller. Shell consisting of a round body with radiations and 2 wings; hinge line straight and toothless; shell rests on the right valve, which is the less convex and has a prominent notch, where the anterior wing joins the body of the shell; muscle near the middle of the body; gill attached by one lamella only: numerous species. Scallops leap and swim by snapping the shell together, giving them a zigzag course; they are used for food, the muscle being usually the only part eaten.

Key to the species of *Pecten* here described:

a_1 Valves with about 20 radiating ribs.....P. IRRADIANS
a_2 Valves with about 50 ribs.....P. ISLANDICUS
a_3 No ribs.....P. MAGELLANICUS

P. irradians* Lamarck. Common scallop (Fig. 905). Shell with about 20 radiating ribs and with numerous lines of growth; wings large and equal in size; color variable, the upper valve being the darker; length 75 cm.; breadth a little less; 30 to 40 bright blue eyes in the edge of each mantle: Cape Cod to Texas, locally farther north; often abundant among eel grass and over mud flats.

Fig. 905—*Pecten irradians* (Verrill).

P. islandicus (Mül.). Shell with over 50 narrow ribs; wings unequal in size, length 9 cm.; width 75 mm.: Cape Cod to Arctic Ocean; Europe.

P. magellanicus† (Gmelin). Giant scallop. Shell without ribs but covered with fine radiating striations, 17 cm. long; wings equal in size; upper valve brown, lower white: New Jersey to Labrador.

Order 4. EULAMELLIBRANCHIATA.

Two gills on each side (Fig. 890, C), each of which is composed of the filamentous leaflets joined by vascular trabeculae (interfilamentary connections) to form a continuous lamella; each gill composed of 2 lamellae, which are the two limbs of the leaflets joined by interlamellar

* See "Habits and Life History of the Scallop (*Pecten irradians*)," by J. Risser, Ann. Com. Fish., Rhode Island, 1901.

† See "Habits, etc., of the Giant Scallop," etc., by G. A. Drew, Stud. Univ. of Maine, No. 6, 1906.

partitions, the ascending limb of the outer leaflet being united with the mantle; genital glands have independent openings to the outside; two adductor muscles usually present; mantle edges more or less fused and the siphons present (Fig. 888), either in form of closed tubes or not; foot usually large, with byssus little or not at all developed: about 27 families, grouped in 7 suborders, including most pelecypods.

Key to the suborders of *Eulamellibranchiata:*

a_1 Mantle often below, shell usually with no pallial sinus....1. SUBMYTILACEA
a_2 Shell usually thin, with pallial sinus (Fig. 889, 10); siphons usually present.
b_1 Pallial sinus prominent.
c_1 Pallial sinus extending far forwards.....2. TELLINACEA
c_2 Pallial sinus not so large.
d_1 Animals do not bore in solid objects.
e_1 Shell thick and solid and more or less round.....3. VENERACEA
e_2 Shell rather thin and usually elongate.....5. MYACEA
d_2 Animals bore in clay, wood, or rock.....6. PHOLADACEA
b_2 A slight pallial sinus or none present.
c_1 Shell thick, usually ribbed.....4. CARDIACEA
c_2 Shell thin.....7. ANATINACEA

SUBORDER 1. SUBMYTILACEA.

Mantle edges open below; closed siphons and pallial sinus usually absent; 2 adductor muscles; cardinal and lateral teeth (Fig. 889) well developed: about 16 families, in fresh and salt water.

Key to the families of *Submytilacea* here described:

a_1 Animals marine.
b_1 Shells not minute, although in some cases small.
c_1 Shells radially grooved.....1. CARDITIDAE
c_2 Shells not radially grooved.
d_1 Umbo not at forward end.
e_1 Lunule present (Fig. 889, 4).
f_1 Adductor muscle impressions nearly equal in size.
g_1 Shell mostly more than 20 mm. long.....2. ASTARTIDAE
g_2 Shell mostly less than 8 mm. long.....3. CRASSATELLIDAE
f_2 Anterior muscle impression much the longer.....7. LUCINIDAE
e_1 Lunule absent.....4. CYPRINIDAE
d_2 Umbo at forward end.....6. DREISSENSIIDAE
b_2 Shells minute.
c_1 Ligament external.....8. KELLYELLIDAE
c_2 Ligament internal.....9. ERYCINIDAE
a_2 Animals in fresh water.
b_1 Shell large.....5. UNIONIDAE
b_2 Shell minute.....10. CYRENIDAE

FAMILY 1. CARDITIDAE.

Shell heart-shaped or ovate, with radiating ribs or striations, hinge thick, with 1 or 2 cardinal and 1 or 2 lateral teeth; foot with byssus; no closed siphon: about 10 genera, all marine.

Venericardia Lamarck. Shell with a rough periostracum; hinge with 2 large oblique cardinal teeth and 1 lateral in each valve; ligament external: several species on the Atlantic coast.

V. borealis (Conrad) (Fig. 906). Shell with about 20 rounded ribs; umbo elevated and turned forwards, almost to the anterior end in old shells; length 25 mm.; height and width 17 mm.: New Jersey to Labrador; in rather deep water; Pacific coast.

Family 2. ASTARTIDAE.

Shell thick, equivalve, with 2 or 3 strong cardinal teeth in each valve; ligament external; laterals absent or rudimentary; lunule distinct; a short cloacal siphon present: about 12 genera, all marine.

Fig. 906

Fig. 907

Fig. 906—*Venericaudia borealis* (Gould). Fig. 907—*Astarte castanea* (Gould).

Astarte Sowerby. Shell roundly oval, with a smooth surface marked with concentric striations: 20 species, circumpolar.

A. castenea (Say) (Fig. 907). Chestnut shell. Shell thick, ovate; umbo elevated and nearly central; anterior end slightly concave, posterior slightly convex; color chestnut; length and height 25 mm.; width 13 mm.: New Jersey to Nova Scotia; in shallow water; often common.

A. undata Gould. Like the above, with 10 to 20 strongly developed concentric ridges; color brownish-olive; length 25 mm.; height 27 mm.; width 14 mm.: Long Island Sound to Gulf of St. Lawrence, in shallow water; common; Pacific coast.

A. quadrans Gould. Shell triangular, smooth, yellowish in color; umbo central; length 11 mm.; height 10 mm.; width 5 mm.: Long Island Sound to Gulf of St. Lawrence.

Family 3. CRASSATELLITIDAE.

Shell thick, equivalve, more or less triangular; umbo towards the forward end, usually concentrally striated; hinge with 1 or 2 cardinal teeth; lunule distinct; ligament internal; no closed siphons: about 6 genera, all marine.

Fig. 908 *Crassatella mactracea* (Gould).

Crassatellites Krüger. Umbo nearly central, anterior dorsal line straight; 2 cardinal teeth in right valve, and 1 in the left; 1 lateral in each: 1 species on the Atlantic coast.

C. mactracea (Linsley) (Fig. 908). Shell small, solid, with about 14 concentric ribs on the surface; color yellowish-green; 6 mm. long and

2.5 mm. wide: Cape Cod to Texas; common in shallow water; West Indies.

Family 4. CYPRINIDAE.

Fig. 909—*Cyprina islandica* (Gould).

Shell regular, equivalve, more or less oval, thick, with a thick periostracum; ligament external; pallial line sinuous; both siphons complete: numerous species.

Cyprina Lamarck. Umbo nearly central, directed towards the forward end; hinge with 3 diverging cardinal teeth and a posterior lateral in each valve; foot thick: 1 species on the Atlantic coast.

C. islandica (L.) (Fig. 909). Shell thick, coarsely wrinkled, 80 mm. long, 75 mm. high, and 45 mm. wide, dark colored: Long Island to the Arctic Ocean, in rather deep water, but often thrown up on the beach; Europe.

Family 5. UNIONIDAE.* (Naiades.)

Fresh-water clams or mussels. Shell equivalve, with a thick pearly layer and a dark-colored periostracum; umbo towards the anterior end; ligament external and prominent; hinge teeth consisting of cardinals and posterior laterals (Fig. 910), present or not; anal siphon complete but very short; foot large, with byssus only in the young: cosmopolitan; about 1,000 species, of which over 500 occur in this country, all living in fresh-water streams and ponds; some are used for food, and the

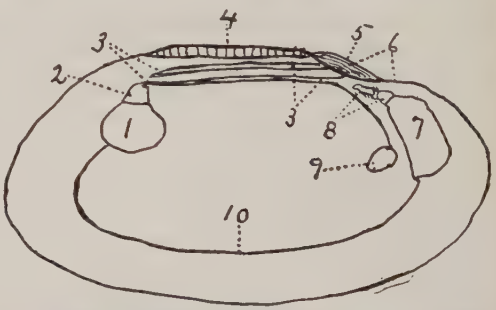

Fig. 910—Diagram of the left valve of *Lampsilis luteolus* (Baker). 1, posterior adductor muscle scar; 2, posterior foot retractor muscle scar; 3, posterior lateral teeth; 4, ligament; 5, umbo; 6, lunule; 7, anterior adductor muscle scar; 8, cardinal teeth; 9, anterior foot retractor muscle scar; 10, pallial line.

* See "Observations on the Genus Unio with Descriptions of New Species," by I. Lea, 13 vols., Philadelphia, 1834-1874. "Synopsis of the Naiades or Pearly Fresh-water Mussels," by C. T. Simpson, Proc. U. S. Nat. Mus., Vol. 22, p. 501, 1900. "A Preliminary List of the Unionidae of West. Penn.," etc., by A. E. Ortmann, Ann. Carn. Mus., Vol. 5, 1909. "Notes upon the Families and Genera of the Naiades," by same, same jour., Vol. 8, 1912. "Notes on the Unionidae and Their Classification," by V. Sterki, Am. Nat., Vol. 37, p. 103, 1903. "Studies on the Reproduction and Artificial Propagation of Fresh-water Mussels," by G. Lefevre and W. C. Curtis, Bull. Bur. Fish., Vol. 30, p. 105, 1912.

shells of many of the thick-shelled species are manufactured into buttons. The eggs are carried usually in the outer pair of gills until the young larvae, which are called glochidia, are hatched. These attach themselves, except in *Strophitus,* to the skin of fishes, in which they become encysted, and there complete their development.

Key to the genera of *Unionidae* here described:

a_1 Hinge teeth (Fig. 910) well developed; shell usually thick.
  b_1 Shell with distinct rays radiating from the umbo (Fig. 911) . . 1. LAMPSILIS
  b_2 No distinct rays.
    c_1 Shell elongate . . . . . 6. UNIO
    c_2 Shell quadrate . . . . . 8. QUADRULA
a_2 Hinge teeth absent or rudimentary; shell thin.
  b_1 Teeth absent.
    c_1 Hinge line not incurved in front of umbo . . . . . 3. ANODONTA
    c_2 Hinge line incurved . . . . . 7. ANODONTOIDES
  b_2 Teeth incomplete or rudimentary.
    c_1 Shell elongate, reniform . . . . . 5. MARGARITANA
    c_2 Shell rhomboid or round.
      d_1 Teeth rudimentary . . . . . 2. STROPHITUS
      d_2 Cardinals present, laterals blurred . . . . . 4. ALASMIDONTA

1. LAMPSILIS Rafinesque. Shell oval or elliptical, usually thick, with a hard, bright, usually rayed periostracum; hinge with 2 cardinals (Fig. 910, 8) and 2 (posterior) laterals in the left and usually 1 of each in the right valve; male and female sexually dimorphic, the female shell being swollen at the base just behind the middle: 128 species, all American.

Key to the species of *Lampsilis* here described:

a_1 Length not twice the height.
  b_1 Length one-third greater than the height.
    c_1 Cardinals strong and prominent.
      d_1 Shell compressed.
        e_1 Umbo and rays prominent . . . . . L. RADIATA
        e_2 Umbo and rays not prominent . . . . . L. LIGAMENTINA
      d_2 Shell very wide . . . . . L. VENTRICOSA
    c_2 Cardinals weak . . . . . L. GRACILIS
  b_2 Length nearly twice the height.
    c_1 Shell large and thick . . . . . L. LUTEOLA
    c_2 Shell small and compressed . . . . . L. IRIS
a_2 Length about 2½ times the height.
  b_1 Color black . . . . . L. RECTA
  b_2 Color yellow . . . . . L. ANODONTOIDES

L. radiata (Gmelin) (Fig. 911). Shell ovate, somewhat angular posteriorly, umbo at the anterior fourth; surface with numerous rays of dusky green; length 75 mm.; height 42 mm.; breadth 30 mm.: Atlantic slope, south to North Carolina; northerly to St. Lawrence slope; west to Manitoba; common.

L. ventricosa (Barnes). Pocket-book clam. Shell swollen, ovate, thick and heavy, rounded before and behind, 15 cm. long, 9 cm. high and 6 cm. wide: valleys of Mississippi and St. Lawrence, in large streams and lakes; common; used in button-making.

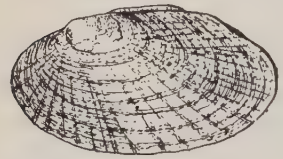

Fig. 911—*Lampsilis radiata* (Gould).

L. gracilis (Barnes). Shell elliptical, compressed, round in front, rounded and very broad behind, 12 cm. long, 7 cm. high, 4 cm. wide; color yellow with green rays extending from the umbo; cardinals weak, but 1 in each valve: Mississippi and St. Lawrence valleys; Hudson River; on muddy bottoms.

L. recta (Lamarck). Black sand shell (Fig. 912, A). Shell elongate, compressed, heavy, rounded in front and triangular behind, 11 cm. long, 5 cm. high, and 3 cm. wide, black in color; 2 cardinals in each valve: Mississippi and St. Lawrence valleys, in large lakes and rivers; used in button-making.

L. anodontoides (Lea). Yellow back. Shell elongate, swollen, triangular behind, 8 cm. long, 35 mm. high, 27 mm. wide, bright yellowish-brown in color; 2 cardinals in each valve: valley of the Mississippi and of the Gulf of Mexico; used in button-making.

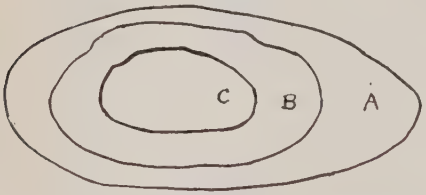

Fig. 912

Fig. 913

Fig. 912—A, *Lampsilis recta;* B, *L. luteola;* C, *L. iris* (Baker). Fig. 913—*Strophitus edentulus* (Baker).

L. luteola (Lamarck) (Fig. 912, B). Shell elliptical, inflated, rounded in front and oval behind, 11 cm. long, 6 cm. high, and 48 mm. wide; color light or dark green; 2 cardinals in each valve: Mississippi and St. Lawrence valleys, in lakes and rivers; common.

L. iris (Lea) (Fig. 912, C). Shell small, elliptical, compressed, 57 mm. long, 3 cm. high, 2 cm. wide; color yellowish, with numerous wide, interrupted, green, radial rays; 2 cardinals in each valve: New York to Illinois, south to Texas; common.

L. ligamentina (Lamarck). Mucket. Shell elliptical, thick, and heavy, 10 cm. long, 6 cm. high, and 35 mm. wide, yellowish or greenish in color, with dark radiating rays; 2 cardinals in each valve: Mississippi and St. Lawrence valleys; used in button-making.

2. Strophitus* Rafinesque. Shell inflated, rounded, with a hard, shining periostracum; teeth rudimentary, consisting of an irregular ridge in the left and 1 or 2 faint ridges in the right valves; male and female shells alike; glochidia not parasitic: 8 species, all American.

S. edentulus (Say) (Fig. 913). Shell ovate, hinder margin forms an obtuse angle with dorsal margin; umbo but little in front of the middle; interior, bluish-white; surface yellowish, with dark rays; length 8 cm.; height 4 cm.; width 3 cm.: eastern and central states.

3. **Anodonta** Lamarck. Shell thin, oval or elongate, inflated; periostracum generally smooth and without rays; hinge without teeth, regularly curved; cloacal siphon without papillae; male and female shells alike: 55 species, 30 American, the animals living usually in muddy streams and ponds, often buried in the mud.

Key to the species of *Anodonta* here described:

a_1 Shell large.
  b_1 Dorsal margin straight.....A. cataracta
  b_2 Umbo with undulating wrinkles.....A. grandis
  b_3 Shell with very thick margins.....A. implicata
a_2 Shell small and bright green.....A. imbecilis

A. cataracta Say (*A. fluviatilis* Gould) (Fig. 914, A). Shell oval, large, crested behind, deep green in color, with obscure radial rays, white within, with a lilac tint; hinge margin straight; 11 cm. long, 7 cm. high, 37 mm. wide; shell rounded in front and forming an obtuse angle behind: Atlantic slope, south to North Carolina; common.

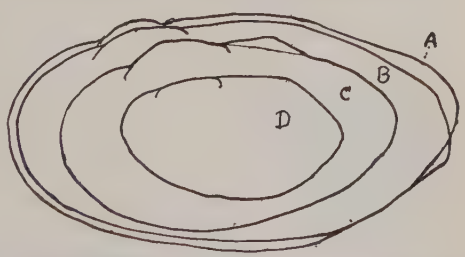

Fig. 914
A, *Anodonta cataracta* (Gould); B, *A. implicata;* C, *A. grandis;* D, *A. imbecilis* (Baker).

A. grandis Say (Fig. 914, C). Shell elliptical, inflated, green or black in color, with usually faint radiating rays, 12 cm. long, 7 cm. high, and 5 cm. wide, or larger; umbo marked with about 5 elevated undulating wrinkles: central states; common.

A. implicata Say (Fig. 914, B). Shell oval, thick and heavy, with a rough, light yellowish-green outer, and a pink inner surface, 10 cm. long, 56 mm. high, and 35 mm. wide; hinder end with a truncated point which is joined with the umbo by a very pronounced edge: Atlantic slope as far south as Virginia; valley of the St. Lawrence.

* "Metamorphosis without Parasitism," etc., by G. Lefevre and W. C. Curtis, Science, N. S., Vol. 33, p. 863.

A. imbecilis Say (Fig. 914, D). Shell very thin and fragile, elliptical, smooth and shining, 59 mm. long, 29 mm. high, and 21 mm. wide; dorsal margin straight; bright grass green in color, with numerous darker radial rays: valley of the Mississippi.

4. **Alasmidonta** Say. Shell elliptical or rhomboidal, inflated, with a well-developed posterior ridge; umbo rather prominent, with a few coarse, parallel ridges; interior surface bluish; hinge with imperfect teeth, 1 large cardinal being under the umbo in the left valve and a smaller one in front of it and 1 cardinal in the right; laterals blurred: 15 species, all in North America, in muddy rivers, often buried several inches in the mud.

Key to the species of *Alasmidonta* here described:

a_1 Shell large.
b_1 Height about half the length.....A. COSTATA
b_2 Height nearly equal to length.....A. COMPLANATA
a_2 Shell small.....A. UNDULATA

A. costata Rafinesque (*A. rugosa* Barnes). Shell elliptical, 16 cm. long, 8 cm. high, and 46 mm. wide; surface with heavy lines of growth, which form prominent wrinkles on the upper posterior portion; yellowish-green in color, with delicate radial rays; cardinals thick: Mississippi and St. Lawrence valleys.

A. complanata Barnes. Hatchet back (Fig. 915). Shell very thick, high, and irregular in shape, the posterior portion being quadrate or triangular; umbo with 4 coarse elevated ridges arranged in a double loop, the apex of which points forwards; color black or brown, sometimes reddish; cardinal in right valve very long; 15 cm. long; 11 cm. high; 5 cm. wide: entire central part of continent, as far south as Arkansas; common; sometimes contains pearls; used in making buttons.

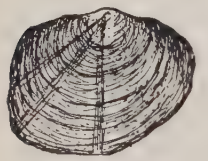

Fig. 915—*Alasmidonta complanata* (Baker).

A. undulata (Say) (Fig. 916, B). Shell short, ovate, inflated, dark green in color, with alternately yellowish and dark radiating rays; umbo large and prominent, with 3 or 4 concentric oblique undulations; 1 cardinal in each valve supported by a strong internal rib; 50 mm. long; 35 mm. high; 25 mm. wide: Atlantic slope, south to South Carolina.

5. **Margaritana** Schumacher. Shell large, elongated; hinge teeth more or less imperfect and small; laterals sometimes wanting: 6 species; circumpolar.

M. margaritifera (L.) (Fig. 916, A). Shell more or less reniform, thick, black in color; umbo not prominent; length 12 cm.; height 5 cm.; width 3 cm.; cardinals, 2 large ones in left valve, the posterior grooved

in front, 1 in right valve also grooved; laterals wanting: circumpolar, as far south as north latitude 40 degrees, but wanting in the central part of the continent; often very common in running streams.

6. **Unio** Retzius. Shell usually thick, oval or elongated, rounded in front and pointed behind; hinge teeth well developed, there being 2 cardinals and 2 laterals in the left, and 1 of each in the right valve; cloacal siphon fringed: circumpolar; 145 species; about 100 American species, mostly in the southern states.

U. gibbosus Barnes (Fig. 916, C). Shell rather elongate, thick and heavy; dull brown in color; umbo marked by 5 or 6 large, wavy ridges;

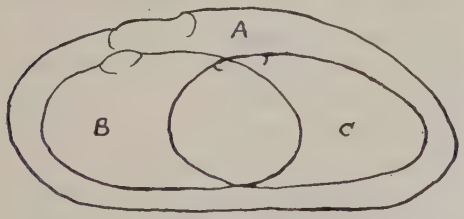

Fig. 916

Fig. 917

Fig. 916—A, *Margaritana margaritifera*; B, *Anadonta undulata* (Gould); C, *Unio gibbosus* (Baker). Fig. 917—*Unio complanatus* (Gould).

length 8 cm.; height 35 mm.; width 20 mm.: valleys of Mississippi and St. Lawrence; also Gulf slope; common.

U. complanatus (Dillwyn) (Fig. 917). Shell ovate, compressed, rather thin, very dark brown or green; interior usually pink; hinge with a single large pyramidal and striated cardinal in the right valve, with a vestige of a tooth in front of it and 2 pyramidal cardinals in the left valve; laterals long and slightly curved; length 10 cm.; width 3 cm.: Atlantic slope, south to Georgia; one of the commonest fresh-water mussels.

7. **Anodontoides** Simpson. Shell elliptical, thin, with a smooth, bright outer surface; umbo with a few coarse, concentric ridges; hinge teeth reduced to mere rudiments or wanting; inner surface bluish-white: 2 species.

Fig. 918
Anodontoides ferussacianus (Baker).

A. ferussacianus (Lea) (Fig. 918). Length 74 mm.; height 39 mm.; width 29 mm.; color grass green, sometimes brown: valleys of the Mississippi and St. Lawrence; common.

8. **Quadrula** Rafinesque. Shell triangular, quadrate or rhomboidal, thick and heavy, inflated; umbo high; hinge teeth well developed; anal siphon with minute papillae or with none; male and female shell-like; both the inner and the outer gills carry the eggs: 100 species, in North America and Asia; 73 American species, mostly in the Mississippi valley.

Key to the species of *Quadrula* here described:

a_1 Shell elliptical.
b_1 Shell smooth.....Q. RUBIGINOSA
b_2 Shell coarsely wrinkled.....Q. UNDULATA
a_2 Shell round.....Q. PUSTULOSA

Q. rubiginosa (Lea). Shell elliptical, thick, compressed, dark yellow in color; umbo marked with 5 or 6 heavy ridges; cardinals double in both valves; 7 cm. long; 6 cm. high, and 3 cm. wide: valleys of the Mississippi and St. Lawrence.

Q. undulata (Barnes). Blue foot (Fig. 919). Shell squarish, compressed, very thick and heavy; umbo marked by 5 coarse diverging ridges; cardinals double in both valves; length 15 cm.; height 10 cm.; width 6 cm.; color brown or black: valleys of Mississippi and St. Lawrence; also Gulf slope; common; used for button-making.

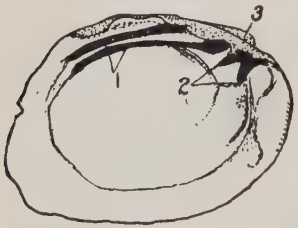

Fig. 919—*Quadrula undulata* —inner surface of left valve (Baker). 1, laterals; 2, cardinals; 3, umbo.

Q. pustulosa (Lea). Shell round, inflated, thick, and heavy, 59 mm. long and high and 36 mm. wide, yellowish-brown in color, with a broad band of dark green extending from the umbo to the ventral border; cardinals double in both valves: Mississippi valley; Michigan; Gulf slope.

Family 6. DREISSENSIIDAE.

Shell like *Mytilus* without its pearly lining; umbo at the interior end; mantles fused below, with both siphons complete and prominent; foot small, with byssus: 2 genera; marine.

Congeria Partsch. With the characters of the family: several species.

D. leucophæta (Conrad). Shell 13 mm. long, 7 mm. high, 6 mm. wide; outer surface rough and brownish: Maryland and southwards, on oysters in brackish water.

Family 7. LUCINIDAE.

Shell round, equivalve, compressed; anterior muscle impression narrower and much longer than the posterior; foot very long, without byssus; mantle open below; siphons usually incomplete; ligament more or less internal: 200 species.

Key to the genera of *Lucinidae* here described:

a_1 Hinge teeth present.....1. Lucina
a_2 No teeth.....2. Cryptodon

1. Lucina Bruguière. Hinge teeth consisting of 1 or 2 cardinals and usually 2 laterals in each valve; lunule distinct; foot sometimes twice as long as the animal, and hollow: 100 species.

L. filosa Stimpson (Fig. 920). Shell thick, regular; hinge margin straight; surface whitish, with prominent lines of growth; 1 cardinal in the left and 2 in the right valve; no laterals; length and height 37 mm.; width 15 mm.: Arctic Ocean to Patagonia, in rather deep water.

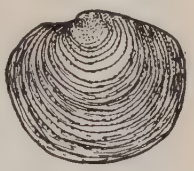

Fig. 920—*Lucina filosa* (Gould).

2. Cryptodon Turton. Teeth absent; foot long and very slender: 16 species.

C. gouldi (Philippi). Shell minute, white, 7.5 mm. long, 8 mm. high, 2.5 mm. wide: Long Island to Gulf of St. Lawrence, in 6 to 300 fathoms.

Family 8. KELLYELLIDAE.

Shell minute, thin, equivalve, round or oval; hinge with 1 or 2 cardinals, a prominent anterior lateral, which is beneath the cardinal, and a posterior lateral, which may be wanting; ligament external; no pallial sinus; mantle open below; anal siphon complete: 1 species on the Atlantic coast.

Turtonia Forbes and Hanley. Shell attached by a byssus; shell oval: in northern seas.

T. minuta (Fabricius) (Fig. 921). Length 2 mm.; height 1.2 mm.; width 1 mm.; color yellowish inside and out, blending into purple on the umbo: circumpolar, south to Cape Cod and Alaska; common under stones at low-water mark and among the roots of seaweed; Europe.

Family 9. ERYCINIDAE.

Shell minute, thin, equivalve; hinge with 1 or 2 cardinals of which the anterior one is oblique; laterals not constant; ligament internal; no pallial sinus; mantle united below, with 3 openings, a posterior anal opening, a median one for the foot, and an anterior branchial opening; foot long, with byssus; viviparous: marine; 5 genera.

Fig. 921

Fig. 922

Fig. 921—*Turtonia minuta* (Gould). Fig. 922—*Kellia planulata* (Gould).

Kellia Turton. Shell without pallial sinus and with 1 lateral tooth in each valve: about 35 species.

K. planulata Stimpson (Fig. 922). Shell minute but not very thin, oval, white, with a brownish periostracum, 4 mm. long, 3 mm. high, and 1.5 mm. wide: Arctic Sea to Long Island Sound, under stones and in shallow water; not common.

Family 10. CYRENIDAE.

Shell small, oval or more or less triangular, thin, greenish or yellowish in color; 1 to 3 cardinals and both anterior and posterior laterals in each valve; small pallial sinus or none; foot elongate, flattened; ligament external; eggs hatched in the inside pair of gills; mantle open below with more or less complete siphons: several hundred species, all in fresh or brackish water, living usually in small streams, ponds, and lakes, either in or on sand or mud or on submerged plants; the young have a byssus by which they often suspend themselves.

Key to the genera of *Cyrenidae* here described:

a_1 Umbo median or towards the anterior end.....1. Sphærium
a_2 Umbo towards posterior end.....2. Pisidium

1. Sphærium Scopoli (*Cyclas* Bruguière). Shell thin, ovoid, greenish; cardinals small or rudimentary, 1 arched cardinal being in the right and 2 in the left valve; laterals compressed; umbo usually a little in advance of the middle; siphons elongate, of unequal size, the branchial being the largest, and neither being closed except at the base: 75 species; cosmopolitan; about 20 in this country.

Key to the species of *Sphærium* here described:

a_1 Umbo in front of the center; shell solid.
b_1 Lines of growth coarse.....S. stamineum
b_2 Surface almost smooth.....S. striatinum
a_2 Umbo median.
b_1 Shell fragile, light-colored.....S. occidentale
b_2 Shell solid, dark-colored.....S. sulcatum

S. stamineum (Conrad). Shell large, inflated, oval, 14 mm. long, 11 mm. high, and 9 mm. wide; surface shining, yellowish or brownish in color, with coarse lines of growth; umbo made prominent by a number of coarse, rounded ridges: eastern and central states; common.

S. striatinum (Lamarck). Shell elongated, yellowish in color, 10.5 mm. long, 7.5 mm. high, 6 mm. wide, with a smooth shining surface and delicate lines of growth: entire country; common.

S. occidentale Prime (Fig. 923). Shell round, with the umbo median small, fragile, inflated, light yellowish in color, 7.5 mm. long, 7.7 mm. high, 4.5 mm. wide; surface shining, with very fine lines of growth: entire country; very common.

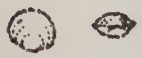

Fig. 923
Sphærium occidentale (Baker).

S. sulcatum* (Lamarck). Shell large, oval, inflated, rather solid, with coarse lines of growth, 18 mm. long, 13 mm. high, and 10 mm. in width; surface smooth and dark brown in color; lateral teeth in a straight line with the cardinals instead of at right angles to them: entire country; not so common as the others.

* See "Anatomy of Sphaerium sulcatum Lam.," by G. A. Drew, Proc. Iowa Acad. Sci., Vol. 3, p. 173, 1895.

2. Pisidium Pfeiffer. Shell minute, round or oval; greenish or yellowish umbo a little back of the middle, and directed backwards; 2 cardinals in the left and 1 in the right valve; laterals lamelliform, 1 in the right and 2 in the left valve; anal siphon alone present; foot tongue-shaped, capable of great extension: 60 species; cosmopolitan; about 20 in America.

Key to the species of *Pisidium* here described:

a_1 Shell triangular.....P. COMPRESSUM
a_2 Shell round or oval.
  b_1 Shell without ventral yellow band.....P. ABDITUM
  b_2 Shell with darker yellow ventral band.....P. VARIABILE
a_3 Pallial sinus very large; siphons separate.

P. compressum Prime. Shell solid, triangular, inflated, very oblique; umbo elevated, with a wing-like appendage on the summit; dorsal margin acutely arched; length and height 4.5 mm.; width 3 mm.; color yellow or brownish: entire country; often common.

P. abditum Haldeman (Fig. 924). Shell oval, solid, 4.25 mm. long, 3 mm. high, and 2.5 mm. wide; surface smooth, shining, bright yellowish in color; 1 arched cardinal in the right and 2 in the left valve; laterals strong and curved: entire country; the commonest species.

Fig. 924 *Pisidium abditum* (Baker).

P. variabile Prime. Shell round, solid, inflated, with umbo very much elevated, 4.5 mm. long and high, and 3.1 mm. wide; surface smooth with heavy lines of growth, light yellow or greenish in color, with a yellow ventral zone: entire country north of Virginia; common.

Suborder 2. TELLINACEA.

Shell equivalve, elongate or more or less triangular; pallial sinus very large, extending forwards sometimes almost to the anterior adductor muscle; mantle edges usually open below; siphons very long, and usually separate; foot and palps large; 2 adductor muscles: 7 families; marine.

Key to the families of *Tellinacea* here described:

a_1 Pallial sinus very large; siphons separate.
  b_1 Ligament external.
    c_1 Inner margin of shell not crenulated.....1. TELLINIDAE
    c_2 Inner margin of shell crenulated.....3. DONACIDAE
  b_2 Ligament partly internal, inserted in a pit in the shell.....2. SEMELIDAE
a_2 Pallial sinus not so large; siphons fused.....4. MACTRIDAE

Family 1. TELLINIDAE.

Shell compressed, equivalve, with 1 or 2 cardinal teeth, and usually 1 lateral in each valve; pallial sinus very large; ligament external, prominent; mantle widely open below and in front; siphons very long, slender, and separated: over 600 species, in all seas, chiefly littoral.

Key to the genera of *Tellinidae* here described:

a_1 Shell over 12 mm. long.
b_1 Shell elliptical; lateral tooth present.....1. TELLINA
b_2 Shell round or ovate; no laterals.....2. MACOMA
a_2 Shell under 6 mm. in length.....3. GASTRANELLA

1. TELLINA L. Shell slightly inequivalve, oval, rounded in front, with an oblique ridge behind; umbo nearly central; 2 cardinals and usually posterior and anterior lateral in each valve: 300 species, chiefly in the tropics, where the shells are often highly colored.

T. tenera Say (Fig. 925). Shell 14 mm. long, 9 mm. high, and 3 mm. wide, thin, delicate, white or pinkish in color, polished, sometimes concentrically banded; umbo a little back of the middle; 1 of the cardinals rudimentary in each valve: Gulf of St. Lawrence to west coast of Florida, on sandy beaches; often common; West Indies.

Fig. 925
Tellina tenera (Dall).

T. tenella Verrill. Shell same in size and color as above; anterior dorsal margin straight or concave; posterior end short and rounded; umbo at the posterior third: Long Island and Vineyard Sounds in 4 to 10 fathoms.

2. MACOMA Leach. Shell oval, round or triangular, equivalve, swollen, gaping at the ends; 2 weak cardinals; no laterals; anal siphon long; branchial short: 100 species, in all seas.

M. tenta Say. Shell oval, very convex, thin, white, with pointed umbo; posterior part narrowed; length 15 mm.; height 10 mm.; width 5 mm.; 2 cardinals in the right and 1 in the left valve: Cape Cod to Florida; common in muddy bays; West Indies.

M. baltica (L.) (Fig. 926). Shell nearly round, thin, slightly narrowed behind, 23 mm. long, 18 mm. high, and 9 mm. wide; 2 cardinals in

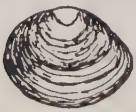

Fig. 926

Fig. 927

Fig. 928

Fig. 926—*Macoma baltica* (Gould). Fig. 927—*Gastranella tumida* (Verrill). Fig. 928—*Cumingia tellinoides* (Gould).

each valve: Arctic Ocean to Georgia, very common in shallow water; in muddy bays the shell is thick, of bluish or rusty color, and covered with a dark periostracum, in sandy localities pure white or pinkish or yellowish and thin; Pacific coast; Europe.

3. GASTRANELLA Verrill. Shell minute, elongate, more or less irregular; 2 cardinals in each valve; no distinct laterals; siphons long and separate: 1 species.

G. tumida Verr. (Fig. 927). Shell with rounded ends, compressed posterially; ventral margin variable, being convex, straight, or concave; color white with purple umbo; length 4 mm.; height 2.5 mm.; width 1.5 mm.: Long Island Sound to Cape Hatteras.

FAMILY 2. SEMELIDAE.

Shell thin, round or ovate, gaping and unusually twisted at the hinder end; external ligament short; internal ligament in a pit; hinge teeth weak: many species.

CUMINGIA Sowerby. Shell oval, often irregular in form; hinge with a small anterior cardinal and usually 2 elongated lateral teeth in each valve: 10 species.

C. tellinoides (Conrad) (Fig. 928). Shell thin and fragile, 15 mm. long, 11 mm. high, 5 mm. wide, rounded in front, and triangular and pointed behind; lateral teeth wanting in the left valve; color bluish-white: Cape Cod to west coast of Florida; West Indies; often common in shallow water.

FAMILY 3. DONACIDAE.

Shell more or less triangular, wedge-shaped, usually thick; ligament external and short; foot very long; mantle open below; gills very different in size: about 6 species, on the southern Atlantic coast; marine or in brackish water.

DONAX L. Shell rounded in front and behind; mantle fringed; 2 cardinals and 1 lateral in each valve: 100 species.

D. fossor Say. Shell small, elongated in front, obliquely rounded and very short behind; surface with radiating striations; inner margin crenulated; length 12 mm.; height 7 mm.; width 4 mm.; color white: south shore of Long Island to Texas, in shallow water; common.

FAMILY 4. MACTRIDAE.

Shell equivalve, more or less triangular, closed or slightly gaping; pallial sinus quite short; 2 ligaments, an external and an internal, the latter contained in a deep triangular pit; hinge with 2 divergent cardinal and usually 2 lateral teeth; mantle open below; siphons long and fused, and with fringed orifices: numerous species.

Fig. 929—*Mactra solidissima* (Gould).

1. **MACTRA** L. Shell slightly gaping at the ends; umbo prominent; foot large: 150 species, in all seas, especially in the tropics.

M. (*Spisula* Adams) **solidissima** Dillwyn. Giant clam (Fig. 929). Shell large and solid; color brown or white; length 15 cm.; height 12

cm.; width 7 cm.: Labrador to Cape Hatteras; common on sandy bottoms in shallow water; sometimes used for food; Europe.

M. lateralis Say. Shell small, triangular, very convex; color white, with a brown periostracum; length 15 mm.; height 12 mm.; width 10 mm.: Nova Scotia to Texas; West Indies; in shallow water on muddy bottoms; often very abundant, especially in Long Island Sound.

2. **Labiosa** Schmidt. Shell oblong, widely gaping, with the posterior dorsal border reflexed and with a distinct ridge below: about 2 species on the Atlantic coast.

L. lineata Say. Shell oval, the surface unequally and slightly wrinkled; color white; length 7 cm.; height 5 cm.; width 28 mm.: New Jersey to Texas; West Indies; in shallow water.

Suborder 3. VENERACEA.

Shell round, oval, or elongate; usually thick and solid; mantle edges usually open below; siphons usually short and more or less united; pallial sinus present; 2 adductor muscles: 3 families, all marine.

Key to the families of *Veneracea* here described:

a_1 Shell regular and thick.....1. Veneridae
a_2 Shell more or less irregular and thin.....2. Petricolidae

Family 1. VENERIDAE.*

Shell regular, heavy; ligament external; hinge usually with 3 diverging teeth in each valve; laterals not constant; pallial sinus usually small; mantle open below: several hundred species, in all seas, those in the tropics often very brightly colored.

Key to the genera of *Veneridae* here described:

a_1 Margin of shell crenulated.
b_1 Shell large with a rough surface.....1. Venus
b_2 Shell small and smooth.....2. Gemma
a_2 Margin not crenulated.
b_1 Shell ovate.....3. Callocardia
b_2 Shell round, as high as long.....4. Dosinia

1. **Venus** L. Shell thick and round or ovate, inner lower margin minutely crenulated; cardinal teeth 3 in each valve; laterals absent; lunule distinct; ligament prominent; siphons short, unequal, and more or less separated; mantle margins fringed: numerous species, in all seas.

V. mercenaria L.† Hard-shell clam. Round clam. Quahog (Fig. 930). Shell ovate or heart-shaped; anterior end short and truncated;

* See "Synopsis of the Family Veneridae and of the North American Recent Species," by W. H. Dall, Proc. U. S. Nat. Mus., Vol. 26, p. 335, 1902.

† See "Clam and Scallop Industries of New York," by J. L. Kellogg, Bull. 43, N. Y. State Museum, 1901. "Feeding Habits and Growth of Venus Mercenaria," by same, Bull. 71, same.

posterior end bluntly pointed; umbo directed forwards; surface dirty white, with prominent, sharp, concentric ridges; inner surface dull white, lower margin violet or purple; length 11 cm.; height 9 cm.; width 6 cm.: Gulf of St. Lawrence to Texas, on sandy and muddy bottoms in shallow water, very common south of Cape Cod; used extensively for food; the shells were used by the Indians in the manufacture of wampum, the violet portion forming the most valuable pieces.

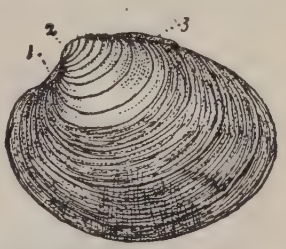

Fig. 930—*Venus mercenaria* (Gould). 1, lunule; 2, umbo; 3, ligament.

V. cancellata L. Shell heart-shaped, white, usually with brown spots; surface with concentric ridges and radial furrows; length 4 cm.; height 27 mm.: Cape Hatteras to west coast of Florida; West Indies.

2. **Gemma** Deshayes. Shell round, the umbo being nearly central; 3 cardinal teeth in the left and 2 in the right valve; pallial sinus long, narrow, and ascending; lunule indistinct; margin crenulated within: 1 species on the Atlantic and Pacific coasts.

G. gemma (Totten). Gem shell (Fig. 931). Shell small, with a smooth shining surface and concentric ridges; color yellowish, white, or pink; umbo and hinder end amethyst; length 4 mm.; height 3.5 mm.; width 2 mm.: Labrador to Cape Hatteras, in the sand in shallow water or between tide marks; often very common; San Francisco.

Fig. 931 *Gemma gemma* (Gould).

3. **Callocardia** Adams. Similar to *Venus,* but the margin of the shell is not crenulated; hinge with 3 cardinal teeth in each valve and 1 or 2 laterals: numerous species; cosmopolitan.

C. convexa Say (Fig. 932). Similar in appearance to *Venus mercenaria;* length 43 mm.; height 35 mm.; width 24 mm.; no purple on inner surface; siphons very long: Nova Scotia to Florida; often common.

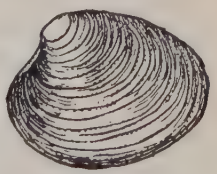
Fig. 932—*Callocardia convexa* (Gould).

4. **Dosinia** Scopoli. Shell orbicular, compressed, with concentric ridges; hinge like *Callocardia;* lunule distinct; margin of shell not crenulated; pallial sinus large, oblique, ascending; siphons united throughout: 100 species, in shallow water.

D. discus Reeve. Shell smooth, with 5 regular concentric grooves; umbo pointed, with a large oblong groove underneath; muscle impressions very large; color yellowish-white; length 66 mm.; height 61 mm.; width 22 mm.: Virginia to Texas; common.

Family 2. PETRICOLIDAE.

Shell elongate, or more or less irregular in form, thin, and with ends rounded; 2 or 3 delicate teeth in each valve; no laterals; pallial sinus deep; mantle closed in front with an opening for the small foot; siphons long, united at the base: 2 genera, in shallow water and between tides, where the animals bore into clay, limestone, and coral, making round holes the diameter of the shell.

Petricola Lamarck. With the characters of the family: 13 species.

P. pholadiformis Lam. (Fig. 933). Shell elliptical, swollen, gaping; umbo near anterior end; surface curved, with radiating grooves and ridges, those at the anterior end being coarse, those back of the umbo being fine; length 32 mm.; height 17 mm.; width 15 mm.; interior with radiating furrows: Gulf of St. Lawrence to Texas, common south of Cape Cod, boring in clay.

Fig. 933—*Petricola pholadiformis* (Gould).

Suborder 4. CARDIACEA.

Shell equivalve, solid, with or without hinge teeth; ligament external; 1 or 2 adductor muscles; siphons short; mantle closed below, with an opening for the foot; with or without pallial sinus: 8 families, all in salt or brackish water, to one of which belongs the gigantic *Tridacna gigas* of the Pacific, the shell of which may weigh over 200 kilograms and measure a meter or more in length.

Family CARDIIDAE.*

Shell heart-shaped, usually with radiating ridges or bands, more or less chalky in texture; ligament short and prominent; pallial sinus small or absent; a small and a large cardinal in each valve; laterals not constant but usually present; inner border of shell denticulate; 2 adductor muscles; mantle open below; siphons short; foot very large and bent: 200 species; cosmopolitan.

Key to the genera of *Cardiidae* here described:

a_1 Shell with radial ribs.....1. Cardium
a_2 Shell without ribs.
b_1 Shell small; teeth large.....2. Lævicardium
b_2 Shell large; teeth small or wanting.....3. Serripes

1. Cardium L. Cockle. Shell with prominent ribs and thick, often with spines or scales, closed or gaping behind; no pallial sinus; umbo

* See "Synopsis of the Family Cardiidae and of the North American Species," by W. H. Dall, Proc. U. S. Nat. Mus., Vol. 23, p. 381, 1900.

near the center of the shell; siphons very short, and separate; 1 or 2 cardinals, 1 or 2 posterior laterals and 2 anterior laterals in the right valve, and 2 cardinals, 1 anterior and 1 posterior lateral in the left valve; mantle margin with papillae: 100 species.

Key to the species of *Cardium* here described:

a_1 Shell large.
b_1 Occurs north of Cape Cod.....C. ISLANDICUM
b_2 Occurs in the southern states.....C. MAGNUM
a_2 Shell small.....C. PINNULATUM

C. islandicum L. Shell large, rounded, with about 36 ribs separated by deep grooves, and with concentric lines of growth; periostracum yellowish-brown, forming a stiff fringe on the edges of the ribs, but often absent in the dead shell; length 5 cm.; height somewhat less; width 25 mm.: circumpolar, south to Cape Cod and Puget Sound, in 5 to 50 fathoms; Europe.

Fig. 934 *Cardium pinnulatum* (Gould).

C. pinnulatum Conrad (Fig. 934). Shell round, small, thin, with about 26 ribs with a row of arched scales on each, inside with furrows corresponding to the ribs; length 11 mm.; height 10 mm.; width 7.5 mm.; color white, interior white or pink: Cape Cod to Labrador, in 1 to 200 fathoms.

C. magnum Born. Shell large, with about 35 ribs; color yellowish-brown, with transverse rows of brown spots; length 10 cm.; height 11 cm.; width 75 mm.: Virginia to Texas, in shallow water; West Indies.

2. **LÆVICARDIUM** Swainson. Shell oval, oblique; umbo nearly central, surface smooth or with slight radial striations: 20 species.

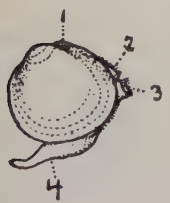

Fig. 935—*Lævicardium mortoni* (Gould). 1, ligament; 2, cloacal siphon; 3, branchial siphon; 4, foot.

L. mortoni (Conrad) (Fig. 935). Shell small, thin, globular, pale fawn color sometimes with brown spots, within bright yellow, with a purplish blotch posterially; surface smooth, without ribs; length 25 mm.; height 22 mm.; width 17 mm.: Nova Scotia to west coast of Florida, in shallow water; very common south of Cape Cod on sandy flats.

3. **SERRIPES** Beck. Shell nearly round, compressed, rather thin; umbo nearly central, prominent; surface smooth or slightly radiated; cardinals and laterals obtuse, almost wanting: 1 species, on both coasts.

S. grœnlandicus (Gmelin). Shell 70 mm. long, 55 mm. high, and 30 mm. wide; white or drab in color; margin slightly crenulated; foot serrated: circumpolar, south to Cape Cod and Puget Sound.

Suborder 5. MYACEA.

Shell either regular or irregular, not pearly, with or without hinge teeth; ligament internal or external; siphons long; pallial sinus present; 2 adductor muscles; mantle closed below with an opening for the small foot: 5 families, all marine; all burrowing in sand, mud, or rock.

Key to the families of *Myacea* here described:

a_1 Shell long and narrow, margins usually parallel.....2. Solenidae
a_2 Shell not long and narrow.
b_1 Left valve with shelf-like process for ligament.....1. Myidae
b_2 No such process.....3. Saxicavidae

Family 1. MYIDAE.

Shell rather thick, inequivalve, gaping at one or both ends; ligament internal, attached in left valve to a prominent shelf-like process; hinge teeth variable; periostracum wrinkled; pallial sinus large; siphons partially or wholly retractile, united: 250 species.

Key to the genera of *Myidae* here described:

a_1 Hinge toothless.....1. Mya
a_2 Hinge with a tooth on each valve.....2. Corbula

1. Mya L. Shell oblong, gaping behind and more or less irregular; siphons very long and partially retractile, covered with periostracum; hinge toothless; foot small, with byssus in youth: 3 species, 2 on the Atlantic and Pacific coasts.

M. arenaria L. Soft-shell clam. Long clam (Fig. 936). Shell ovate, white, covered with a brownish periostracum; length 10 cm.;

Fig. 936

Fig. 937

Fig. 936—*Mya arenaria* (Verrill). 1, foot; 2, mantle; 3, cloacal siphon; 4, branchial siphon. Fig. 937—*Corbula contracta* (Gould).

height 6.5 cm.; umbo nearer anterior end: Arctic Sea to Cape Hatteras, between tide lines and in shallow water in mud flats and under stones; San Francisco; Europe; a common article of food.

M. truncata L. Shell truncated behind; periostracum thick and extended posteriorly, forming a tube 15 cm. long; length 7 cm.; height 4 cm.; width 3 cm.: circumpolar, south to Cape Cod and Puget Sound; not common; Europe, where it is more plentiful than *M. arenaria.*

2. Corbula Bruguière. Shell small, inequivalve, thick, gaping in front; hinge with an upright tooth in each valve which fits into a pit in the other; siphons short: 75 species.

C. contracta Say (Fig. 937). Shell 10 mm. long, 6 mm. high, and 5 mm. wide, with a broad, rounded anterior and a pointed posterior end; surface with regular, smooth, concentric ridges: Cape Cod to Florida, in sand and mud.

Family 2. SOLENIDAE.

Shell thin, equivalve, long, and narrow, and with gaping ends; ligament external; 1 to 3 cardinals in each valve; no laterals; foot large, cylindrical; siphons short, united about half their length: 100 species.

Key to the genera of *Solenidae* here described:

a_1 Margins parallel.....1. Ensis
a_2 Margins not parallel; shell elliptical.
b_1 Pallial sinus short.....2. Siliqua
b_2 Pallial sinus very long.....3. Tagelus

1. Ensis Schumacher. Razor clams. Shell very long and narrow, with parallel margins, with a slight bend making the dorsal side concave and the ventral convex; 2 hinge teeth in the right and 3 in the left valve near the anterior end; umbo near same end: 14 species; in shallow water.

E. directus Conrad (Fig. 938). Shell about 6 times as long as high; ends truncate; right valve with 1 projecting tooth and an elongated ridge-like tooth back of it; left valve with 2 projecting teeth and a double ridge;

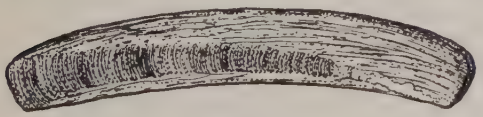

Fig. 938

Fig. 939

Fig. 938—*Ensis directus* (Gould). Fig. 939—*Siliqua costata* (Gould).

length 15 cm.; height 25 mm.; width 16 mm.; color yellowish or greenish: Labrador to west coast of Florida, common in the sand, in which it buries itself by a digging motion of the foot.

E. viridis (Say). Shell about 5 times as long as high; dorsal margin nearly straight; anterior end truncate, posterior rounded; hinge with 1 tooth in each valve; periostracum light green, glossy; length 5 cm.; height 10 mm.; width 6 mm.: Rhode Island to west coast of Florida.

2. Siliqua Mühlfeldt. Shell elliptical, smooth, with a rib extending from the umbo across the shell on the inner surface; pallial sinus short; 2 cardinals in the right and 3 in the left valve: 20 species.

S. costata (Say) (Fig. 939). Shell thin, shining, with a greenish periostracum, 45 mm. long, 18 mm. high, 7 mm. wide: Nova Scotia to Cape Hatteras, in the sand in shallow water; often very common.

3. **Tagelus** Gray. Shell elongated with the dorsal and ventral margins nearly parallel; umbo central; 2 cardinals in each valve; foot too large to be retracted into the shell; siphons separated at the end; pallial sinus very large: 2 species on the Atlantic coast.

T. gibbus (Spengler) (Fig. 940). Shell thick, rounded at both ends; umbo back of the middle, and ligament back of it; length 9 cm.; height 3 cm.; width 2 cm.: Cape Cod to Texas, common on muddy bottoms in shallow water, in which it burrows; Europe

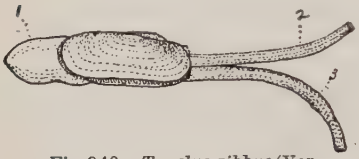

Fig. 940—*Tagelus gibbus* (Verrill). 1, foot; 2, cloacal siphon; 3, branchial siphon.

T. divisus (Speng.). Shell small and delicate, elliptical in shape, ends rounded, the posterior being somewhat more acute than the anterior; umbo nearly central; length 35 mm.; height 12 mm.; width 9 mm.; surface smooth, with a band of purple passing from the umbo across the shell: Cape Cod to west coast of Florida; West Indies.

Family 3. SAXICAVIDAE.

Shell thick, equivalve, gaping at the ends; hinge toothless or with 1 or 2 cardinals; ligament external, prominent; pallial line sinuous; pallial sinus present; mantle margins fused, leaving a small opening for the small foot; siphons large and long, united, covered with a thick periostracum: 25 species; cosmopolitan.

Key to the genera of *Saxicavidae* here described:

a_1 Umbo nearer the anterior end.....1. Saxicava
a_2 Umbo nearer the posterior end.....2. Cyrtodaria

1. **Saxicava** Bellevue. Shell symmetrical when young, with 2 minute teeth in each valve; adult irregular in shape, toothless; surface coarse; ligament external: 12 species, which bore in soft rock and coral.

S. arctica (L.) (Fig. 941). Shell very variable in form, more or less elliptical, the right valve projecting partly over the left and generally gaping; length 25 mm.; height 15 mm.; width 10 mm.; surface divided by 2 radiating ridges into 3 equal portions; color white, periostracum yellowish: nearly cosmopolitan; circumpolar, south to the west coast of Florida and Santa Barbara, Cal.; very common north of Cape Cod, boring in limestone or retreating in crevices of the rocks, among the roots of seaweed, etc.

Fig. 941
Saxicava arctica (Gould).

2. **Cyrtodaria** Daudin. Shell elliptical, the posterior end the shorter; hinge thick, without teeth; ligament external; animal much too large for the shell: 1 species on the Atlantic coast.

C. siliqua (Sprengler). Shell very thick and heavy; length 85 mm.; height 35 mm.; width 24 mm.; periostracum thick and black: Cape Cod to the Arctic Ocean, in deep water.

Suborder 6. PHOLADACEA.

Shell more or less modified by the boring habit; ligament and hinge absent; mantle closed; siphons very long and united almost their whole length; foot short, often more or less rudimentary; 3 adductor muscles: 2 families, marine, the animals boring long passages in wood, rock, or clay by means of a rasping motion of the shell.

Key to the families of *Pholadacea:*

a_1 Shell large; siphons long.....1. Pholadidae
a_2 Shell small; siphons many times as long as shell; shipworms..2. Teredidae

Family 1. PHOLADIDAE.

Shell rather large, thin, fragile, white, gaping at both ends, armed in front with rasp-like ridges; pallial sinus deep; dorsal margin of shell reflected in part over the umbo; one or more accessory dorsal valves; an interior curved muscle process extending from the umbonal cavity: 80 species, which bore symmetrical holes in clay, wood, or rocks; about 12 species on the Atlantic coast.

Key to the genera of *Pholadidae* here described:

a_1 Dorsal margin of shell reflected over the umbo.....1. Pholas
a_2 Dorsal margin but slightly reflected.....2. Zirphæa

1. Pholas L. Shell elongated and very convex; dorsal margin protected by 2 accessory valves; foot large: 20 species, in all seas.

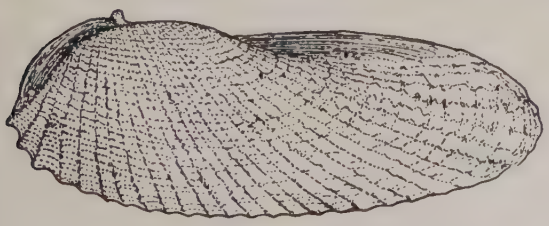

Fig. 942

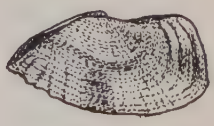

Fig. 943

Fig. 942—*Pholas costata* (Gould). Fig. 943—*Pholas truncata* (Gould).

P. costata L. (Fig. 942). Shell large, 15 cm. long, 5 cm. high, and 5 cm. wide, with about 30 radiating, serrated ribs, the interior being marked by corresponding depressions; umbo near anterior end; accessory valves horny, not calcareous: Cape Cod to South America, forming deep burrows in the clay; common in the southern states, rare towards the north; Europe.

P. truncata Say (Fig. 943). Shell 73 mm. long, 37 mm. high, and 31 mm. wide; elongate; anterior end triangular and sharply pointed, posterior end broad and truncated; anterior portion with radiating ridges; accessory valves calcareous: Massachusetts Bay to west coast of Florida; common in the southern states.

2. ZIRPHÆA Leach. Shell oval; cardinal margin slightly reflected; no accessory valves; umbo protected by a membrane: 3 species.

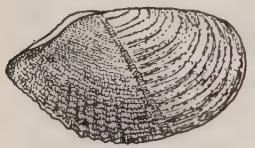

Fig. 944—*Zirphœa crispata* (Gould).

Z. crispata (L.) (Fig. 944). Shell thick, white, rounded posteriorly, triangular and pointed anteriorly, gaping widely at both ends; surface divided into equal halves by a broad furrow extending from the umbo to the lower margin, the anterior half marked by numerous coarse ridges; length 60 mm.; height 35 mm.; width 34 mm.: circumpolar, south to Cape Hatteras and California, boring in clay and wood in 9 to 70 fathoms, common towards the north; Europe.

FAMILY 2. TEREDIDAE.

Ship worms. Animal vermiform, with very long siphons which are united the greater part of their length and have 2 calcareous pieces called the pallets (Fig. 945, 2) at the point where they separate; valves 3-lobed, very small, gaping at both ends, forming thus a ring with an interior curved muscle process extending from the umbonal cavity: 2 genera; 7 species on the Atlantic coast; the animals live in long burrows in wood or clay, which they form probably by the rasping motion of the shells and then line with a calcareous coating; they often do great damage to ships and docks; the burrows usually follow the grain of the wood, but not always, and usually do not run into one another.

Key to the genera of *Teredidae:*

a_1 Pallets spatulate.....1. TEREDO
a_2 Pallets feather-shaped.....2. XYLOTRYA

1. TEREDO L. Body globular, lying at the inner end of the burrow; valves 3-lobed, the center lobe being the largest; mantle lobes united, with a minute opening for the foot; siphons united nearly to the end: about 20 species, 6 on the Atlantic coast.

Key to the species of *Teredo* here described:

a_1 Tubes about 6 mm. in diameter.
  b_1 Stalk and blade of pallet of equal length.
    c_1 Posterior lobes of shell much larger than the anterior.....T. NAVALIS
    c_2 Posterior and anterior lobes of equal size.....T. NORVEGICA
  b_2 Blade of pallet much longer than the stalk.
    c_1 Blade of pallet obovate.....T. MEGOTARA
    c_2 Blade of pallet oval.....T. THOMPSONI
a_2 Tubes about 3 mm. in diameter.....T. CHLOROTICA

T. navalis L. (Fig. 945). Length of tube usually 25 cm. or less, but sometimes much greater; diameter of tube 6 to 10 mm.; length of shell 6 mm.; width 2 mm.; posterior lobes of shell much larger than the anterior; pallets rounded on one side and flat on the other, with the stalk and blade of equal length: Arctic seas to Texas; very common; Europe.

T. megotara Hanley (Fig. 946). Length of tube up to 45 cm.; length and height of shell 6 to 12 mm.; length of pallet 6 mm.; width 3 mm.; posterior lobe large and separated from the umbo by a narrow, deep, rounded notch; stalk of pallet half as long as blade, which is obovate: Arctic seas to South Carolina; common in floating wood; Europe.

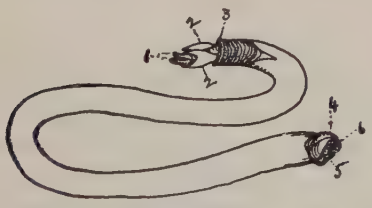

Fig. 945

Fig. 946

Fig. 945—*Teredo navalis* (Verrill). 1, ends of the siphons; 2, pallets; 3, muscular collar by which it adheres to the tube; 4, posterior lobe of shell; 5, foot; 6, anterior lobe of shell. Fig. 946—*Teredo megotara* (Gould). 1, shell; 2, pallets.

T. norvegica Spengler. Tube up to 30 cm. long and chambered at entrance; length of shell 14 mm.; height 15 mm.; length of pallet 21 mm.; width 6 mm.; anterior and posterior lobes of shell of about the same length; pallets with stalk and blade of equal length, the latter being truncate: New York to west coast of Florida; Europe.

T. thompsoni Tryon. Length of shell 9 mm.; height 12 mm.; anterior and posterior lobes of equal height; length of pallet 8 mm.; width 3 mm.; blade of pallet oval and much longer than the stalk: Cape Cod to Florida; sometimes common.

T. chlorotica Gould. Burrows very small, lying across the grain of the wood and close together so as to resemble a honeycomb; length and height of shell 3 mm.; pallet, paddle-shaped, 5 mm. long: Massachusetts Bay to Florida.

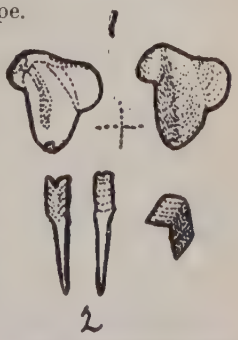

Fig. 947—*Xylotrya fimbriata* (Gould). 1, shell; 2, pallets.

2. **Xylotrya** Leach. Pallets long and feather-shaped, the blade consisting of articulated pieces radiating obliquely from the stalk: 10 species.

X. fimbriata Jeffreys (Fig. 947). Shell similar to that of *Teredo navalis;* length of pallet 12 mm.; width 2 mm.; tubes 30 cm. or more long: Massachusetts Bay to Florida: often common.

Suborder 7. ANATINACEA.

Shell thin, white and pearly; hinge with or without teeth; ligament external; mantles united, except where the foot protrudes; 2 adductor muscles; pallial line variable; siphons mostly united: 11 families, all marine, including many degenerate forms, which may lack certain organs, as the foot, adductor muscles, labial palps, and gills.

Key to the families of *Anatinacea* here described:

a_1 No spatulate hinge lamella.
b_1 Pallial sinus slight or absent.....1. Pandoridae
b_2 Pallial sinus angulated.....2. Lyonsiidae
a_2 Hinge lamella in each valve.....3. Anatinidae

Family 1. PANDORIDAE.

Shell free or fixed, inequivalve, pearly inside, semi-lunar or triangular in shape; ligament often with a calcareous ossicle; pallial line with or without a small sinus; siphons short, united except at the end; mantle margins united: about 5 species on the Atlantic coast.

Clidiophora Carpenter. Shell thin; valves closed, attenuated behind; right valve flat, with a diverging ridge; left valve somewhat convex, with 2 diverging grooves at the hinge; a slight pallial sinus: numerous species.

Fig. 948

Fig. 949

Fig. 948—*Clidiophora triliniata* (Gould). 1, siphons; 2, foot.
Fig. 949—*Lyonsia hyalina* (Gould).

C. trilineata (Say) (*C. gouldiana* Dall) (Fig. 948). Shell rounded in front, hinder end curved upwards, making the dorsal margin straight or concave; length 32 mm.; height 17 mm.; width 5 mm.: Nova Scotia to Texas, in shallow water; common.

Family 2. LYONSIIDAE.

Shell thin, slightly inequivalve, the left valve being the larger; pallial sinus obscure; hinge teeth absent; hinge with a narrow ledge within each valve, to which adheres an ossicle; siphons very short: several genera.

Lyonsia Turton. With the characters of the family: 18 species.

L. hyalina (Conrad) (Fig. 949). Shell ovate, pearly, and transparent; anterior end rounded; posterior end elongated; dorsal line nearly

straight; pallial line obscure; surface with radiating fringed wrinkles; periostracum dirty white; length 17 mm.; height 10 mm.; width 7.5 mm.: Nova Scotia to Texas, in shallow water; common.

Family 3. ANATINIDAE.

Shell thin, more or less inequivalve, exterior often granular; hinge toothless or with a spatulate lamella; ligament often with an ossicle; pallial line obscure: 14 species on the Atlantic coast.

1. Thracia Blainville. Shell nearly equivalve, gaping behind, smooth; siphons rather long, separate; umbo prominent; spatulate process of hinge in each valve, and very oblique: 26 species.

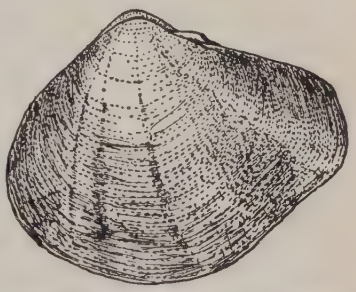

Fig. 950—*Thracia conradi* (Gould).

T. conradi Couthouy (Fig. 950). Shell thin, almost round, somewhat elongated and truncated behind, whitish in color; ligament prominent; pallial sinus deep; periostracum thin and brown; length 75 mm.; height 65 mm.; width 38 mm.: Labrador to Cape Hatteras, buried deep in the sand or mud in shallow water.

2. Cochlodesma Couthouy. Shell oval, inequivalve, slightly gaping at both ends; hinge with a spatulate process in each valve and a small ossicle; an internal rib extends from the hinge to the posterior margin; siphons long and separate: several species.

Fig. 951
Cochlodesma leanum (Gould).

C. leanum (Conrad) (Fig. 951). Shell oval, very thin; right valve the more convex, the left valve being nearly flat; length 35 mm.; height 25 mm.; width 11 mm.: Nova Scotia to Cape Hatteras; common in shallow water.

Order 5. SEPTIBRANCHIATA.

Ctenidia absent, but replaced by a muscular septum (Fig. 890, D) pierced by slits extending from the anterior adductor muscle to the point of separation of the siphons and dividing the mantle cavity into 2 chambers, one lying above the other: 2 families.

Family CUSPIDARIIDAE.

Shell small, slightly inequivalve, not pearly, much attenuated and gaping behind; a spatulate cartilage process in each valve; hinge teeth present or absent; pallial line shallow; mantle closed; siphons short and united: about 20 species on the Atlantic coast, mostly in deep water.

Cuspidaria Nardo. Shell slender behind and broader in front, the right valve being the smaller; umbo strengthened internally by a rib: numerous species.

C. pellucida Stimpson. Shell thin, white, 12 mm. long, 7.5 wide; umbo a little in front of the center: Cape Cod and northwards, in deep water.

Class 5. CEPHALOPODA.*

Squids, devilfish, etc. Marine mollusks often of large size and of high organization, which have a large head and large eyes and a circle of long arms or tentacles around the mouth, and are mostly without an external shell (Fig. 740, A).

External Structure.—The body is a bilaterally symmetrical, more or less cylindrical structure, which is elongated dorsally and made up of two divisions, the head and the trunk. The head is the ventral portion of the body, in the middle of the lower surface of which is the mouth, surrounded by the arms. In *Nautilus* the arms are about ninety in number and are without suckers; in the other cephalopods they are either eight or ten in number and are provided with either prehensile suckers or hooks, or with both these structures.

The trunk is made up of the visceral mass (Fig. 740, A, 1) and the mantle (A, 2). The visceral mass is a compact cylindrical structure with delicate body walls. The mantle is thick and muscular and covers the visceral mass on all sides, its lower edge being called the collar. The mantle cavity (A, 4) is voluminous, and is posterior in position and contains the gills and the external openings of the digestive, excretory, and reproductive organs. It communicates with the outside in two ways, through the open space around the collar and by means of a conical, muscular tube called the siphon or funnel (A, 5). By the contraction of its muscular walls the water in the mantle cavity is shot violently out through the siphon, and the animal is propelled rapidly through the water in the opposite direction; water is taken into the mantle cavity again through the collar space. The head and the siphon can be partially retracted within the mantle by means of powerful retractor muscles. The external surface is covered with an integument in which amœboid pigment cells are present, by the alteration in size of which the color of the animal may be rapidly changed. Many cephalopods are brilliantly colored.

A shell is present in all cephalopods except in most *Octopoda*. In *Nautilus, Spirula,* and *Argonauta* the shell is calcareous, external, coiled in a single plane, and in *Nautilus* and *Spirula* divided into chambers by

* See "Report of the Cephalopods of the Northeastern Coast of America," by A. E. Verrill, Rep. U. S. Fish. Com. for 1879, p. 221, 1882.

transverse partitions. The shell of *Argonauta,* the paper nautilus, is not homologous to that of other cephalopods. In the *Decapoda,* the shell is concealed in a pocket of the anterior wall of the mantle. It differs much in shape and composition in the various species, being calcareous in *Spirula* and *Sepia,* but coiled in the former and straight in the latter, and chitinous and elongate in the squids.

The foot is absent in cephalopods in the form in which it occurs in other mollusks. The siphon, however, represents the fused epipodia and the arms are lateral processes of the foot, the basal portion of which has grown forwards and enveloped the head, so that the mouth comes to lie in their midst.

Internal Structure.—The mouth is surrounded by a ring-shaped lip and leads into a muscular pharynx. A pair of sharp chitinous or partly calcareous jaws, which look a good deal like a parrot's beak, lie just back of the lip, by means of which the animal tears its prey to pieces. In the pharynx are the tongue and the radula. The radula is small, as compared with the size of the animal, and consists of a central tooth and three laterals in each transverse row; marginals are absent in the *Decapoda,* and are represented in the *Octopoda* by a plate of varying shape. Two pairs of salivary glands pour their secretion into the pharynx; in the *Decapoda* the anterior glands are united or may be rudimentary.

The œsophagus is a narrow tube which leads to the stomach; in *Nautilus* and the *Octopoda* a lateral crop is present. The stomach is a muscular organ with a large thin-walled cæcum, which acts as a gall bladder and receives the secretion of the large liver. The two ducts which pass to the stomach cæcum from the liver have in their walls a paired gland called the pancreas. The intestine leaves the stomach and passes forward to the anus in the mantle cavity. A glandular pocket at the anal end of the rectum, called the ink sac, secretes a brown or black fluid, by means of which the animal clouds the water when fleeing from an enemy; *Nautilus* is without the ink sac.

The respiratory organs consist of a pair of ctenidia (two pairs in *Nautilus*) which lie in the mantle cavity. These bear a close relation to the circulatory system. There are three hearts. The systemic or arterial heart consists of two auricles (four in *Nautilus*) which receive blood from the gills and pour it into a median ventricle, which distributes it through arteries throughout the body. The blood returns through large veins to the two branchial hearts at the base of the gills, which send it through these organs.

The excretory organs consist of a pair of kidneys (two pair in *Nautilus*), which open into the mantle cavity near the anus; they also

open into the pericardial cavity. The kidneys bear a close relation to the large veins bringing blood to the branchial hearts.

The main ganglia are massed together around the forward end of the œsophagus and are surrounded by a protective capsule of cartilage. On the dorsal side of the œsophagus are the cerebral, on the ventral side, lying close together, the visceral (viscero-pleuro-parietal) and the pedal ganglia, which are joined with the cerebral by broad connectives. In front of the pedal are the brachial ganglia, which are genetically a part of them and send off large nerves to the arms. Two pairs of large pharyngeal ganglia, an upper and a lower pair, lie at the base of the pharynx. A pair of large optic ganglia spring from the brain, and a pair of large stellate ganglia, which are joined to the visceral by connectives, lie on the inner surface of the mantle.

The special sense organs are well developed. The eye is a camera obscura consisting of a deep pit with a retina on its inner surface and a small opening to the outside for the admission of light. In *Nautilus* the eye is of this form. In other cephalopods, a large lens is present at the opening, and in most forms a transparent cornea is also present in front of the lens. The superficial similarity of this eye to the vertebrate eye is very striking. A pair of lithocysts, which are organs of equilibrium, lie on the under side of the cerebral cartilage. A pair of pits just behind the eyes are probably olfactory organs. Osphradia are present in *Nautilus*, at the base of the gills.

The sexes are separate. The gonad is single and occupies most of the upper half of the visceral mass. The ducts leading from it are either single or paired; they do not join the gonad directly, but come from a capsule surrounding it, which is a portion of the cœlom, and extend to the mantle cavity. In the female of most decapods large glandular structures called the nidamental glands open into the mantle cavity near the opening of the oviduct, which secrete the egg capsules. The vas deferens is single (except in *Nautilus*) and secretes the spermatophores. These capsules, filled with sperm, are introduced into the mantle cavity of the female by one of the arms of the male, which is often specially modified for this purpose, and is called the hectocotylus arm. In *Argonauta* and one or two other octopod genera, the hectocotylus arm becomes separated from the body and enters the mantle cavity of the female with its load of spermatophores, where it may remain for days, and as it was supposed at one time to be a parasitic worm, it was given a name by Cuvier and called *Hectocotylus octopodis.*

History.—The common cuttle fish of the Mediterranean have been well-known animals for a very long period of time, and were called polyps by Aristotle and the Latin and medieval authors. The class *Cephalopoda*

was created by Cuvier in 1795 to include the same animals it does today. The epoch-making dissection of *Nautilus* by Richard Owen resulted in his subdivision of the class in 1832 into the *Tetrabranchiata* and *Dibranchiata,* and also the subdivision of these orders substantially as is still done.

Distribution and Habits.—Cephalopods occur only in the sea, either in the neighborhood of the coast or in the open ocean or the deep sea. All are carnivorous, eating great numbers of fish, mollusks, and crustaceans, and often being very destructive to the fisheries. Many kinds, as the small squids, swim about in schools, while others, as most octopods, live singly. All cephalopods swim, often with great swiftness, by squirting water out through the siphon, while the squids also swim by means of the fins. The animal carries its body in a horizontal position while swimming, with the posterior side and the siphon undermost. The octopods often crawl about on the bottom on their arms. Cephalopods are the largest invertebrates and among the largest existing animals. *Architeuthis princeps* is the species containing the largest known individuals, the largest examples of which are over fifty feet long, including the arms.

Cephalopods are of use to man in various ways. Many are used for food. The common squids are used as bait in the cod fisheries. The calcareous cuttle bone of the cuttle fish (*Sepia*) was formerly employed as a medicine, and the ink of the same animal is a common artist's material. The shell of *Nautilus* is also much used in the arts, and for a variety of useful purposes.

The class contains two orders and about 400 species: about 5,000 fossil species are known.

Key to the orders of *Cephalopoda:*

a_1 Shell large, coiled, chambered, external.....1. TETRABRANCHIATA
a_2 Shell not coiled (except *Spirula*), internal, often absent..2. DIBRANCHIATA

ORDER 1. TETRABRANCHIATA.

Shell external and coiled and divided by partitions into chambers (Fig. 952), all of which are empty and filled with air or a gas, except the outer one, which contains the body of the animal, and may be as large as all the rest of the shell; septa regularly curved and concave in *Nautilus,* but in the fossil ammonites often very complex in structure, with a membranous tube called the siphuncle extending from the body of the animal through all of them, which is central in position in *Nautilus* and marginal in the ammonites; shell composed of 2 layers, of which the inner is pearly; 4 ctenidia, 4 kidneys, and 4 auricles, but no branchial hearts present; siphon consists of 2 separate lobes (the epipodia); tentacles numerous and without suckers; eye without lens; ink sac absent: about 4 living

and numerous fossil species, grouped in 2 suborders. Of these suborders, the *Ammonoidea,* or the ammonites, were abundant throughout the Mesozoic age and became extinct before its close.

Suborder NAUTILOIDEA.

Shell straight (*Orthoceras*), bent (*Cyrtoceras*), loosely (*Gyroceras*), or closely coiled (*Nautilus*), in the fossil species, and closely coiled in all the living species; septa concave; siphuncle variable in position, often large: 11 families, with 4 living and 2,000 fossil species, the latter dating back to the Cambrian and reaching their maximum in the Silurian and Devonian ages.

Family NAUTILIDAE.

Shell with few whorls, more or less overlapping; septa simple; siphuncle central or nearly so; tentacles about 90 in number, consisting of 4 groups of 12 or 13 labial tentacles around the mouth, 2 groups of 17 larger tentacles on each side of the head, 2 thicker tentacles, which combine to form a hood beneath which the mouth and its appendages can be retracted, and 2 small tentacles on each side of the eye: 1 genus.

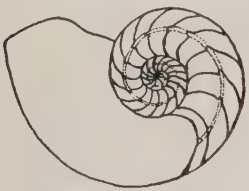

Fig. 952—Section of a nautilus shell (Cambridge Natural History).

Nautilus L. With the characters of the family: 4 species; 300 fossil species.

N. pompilius L.* The pearly nautilus (Fig. 952). Shell up to 25 cm. in diameter, white with chestnut-brown stripes, and pearly inside; body about 18 cm. long: Pacific and Indian Oceans, in rather deep water near the shores; often common; body used for food, and the shell extensively employed for ornamental and useful purposes.

Order 2. DIBRANCHIATA.

Shell internal (except in *Spirula*) or absent, either horny or calcareous, and not coiled (except in *Spirula*); 2 ctenidia, 2 kidneys, and 2 branchial hearts present; siphon tubular; mouth surrounded by either 8 or 10 arms, which have suckers or hooks; ink sac present; eye with a crystalline lens; body cylindrical or globose: about 350 species, grouped in 2 suborders; about 30 species off the Atlantic coast.

Key to the suborders of *Dibranchiata:*

a_1 Ten arms present.....1. Decapoda
a_2 Eight arms present.....2. Octopoda

* See "The Anatomy of Nautilus pompilius," by L. E. Griffin, Mem. Nat. Acad., Vol. 8, p. 103, 1900. "Notes on Living Nautilus," by Bashford Dean, Am. Nat., Vol. 35, p. 819, 1901.

Suborder 1. DECAPODA.

Body either elongate or more or less globose, with a pair of fins at or near the aboral end, and with 10 arms, 4 pairs of shorter arms with suckers along their entire length, and 1 pair of long tentacular arms, often more or less retractile, with the suckers confined to a broad terminal portion; suckers pedunculate and with a chitinous supporting ring; shell (Fig. 953) always present, and either chitinous or calcareous, and consisting, in its typical form (in the fossil *Belemnitidae*), of a solid, conical, terminal rostrum and a chambered conical phragmocone, which corresponds to the shell of *Nautilus,* and is contained in the hollow base of the rostrum, and whose broad, flat, anterior portion is called the proöstracon: about 250 species, grouped in 3 divisions; about 21 species on the Atlantic coast.

Fig. 953 Diagram of a belemnite shell (Leunis). 1, proöstracon; 2, phragmocone; 3, rostrum.

Key to the divisions of *Decapoda:*

a_1 Shell calcareous.
b_1 Shell spiral, with a siphuncle.....1. Phragmophora
b_2 Shell not spiral.....2. Sepiophora
a_2 Shell chitinous.....3. Chondrophora

Division 1. PHRAGMOPHORA.

Shell consists of a phragmocone, the septa of which are pierced by a siphuncle near the inner margin of the whorl, with or without rostrum and proostracon; arms with hooks or suckers: 2 families, in one of which, the fossil *Belemnitidae* of the Mesozoic age, the shell was formed of the 3 typical parts (Fig. 953).

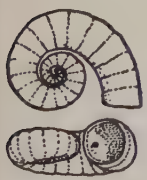

Fig. 954—The shell of *Spirula peroni* (Cambridge Natural History).

Family SPIRULIDAE.

Shell partly internal and partly external, consisting of a loose spiral with 2 or 3 coils, which is the phragmocone alone; siphuncle contained in a continuous calcareous canal: 1 genus.

Spirula Lamarck. With the characters of the family: 1 species.

S. peroni Lam. (Fig. 954). Shell white and pearly, 25 mm. in diameter; body red with brown spots, 55 mm. long, with a terminal sucker: in deep water in tropical seas; the animal has been seen in only a very few cases but the shells are common in the Caribbean Sea, and are occasionally thrown up on the beach on Nantucket and other places along the Atlantic coast.

Division 2. SEPIOPHORA.

Shell consists of a highly modified, calcareous phragmocone with air chambers but without siphuncle, and with a rudimentary rostrum: 1 family.

Family SEPIIDAE.

Body oval; fins narrow, as long as the body, generally united behind; suckers generally in 4 rows; eye with cornea; fourth arm on left hectocotylised: 33 species; cosmopolitan.

Fig. 955
Sepia officinalis (Leunis).
1, tentacular arm; 2, fin.

Sepia L. Cuttle fish. Shell (cuttle bone) calcareous, large, broad, very thick in front, concave internally behind; it was formerly used in medicine as an antacid: 30 species; 10 fossil species.

A. officinalis L. (Fig. 955). Common sepia. Length of body 20 cm.; color brownish with white spots and stripes, and with violet fins: Europe; used for food in the Mediterranean.

Division 3. CHONDROPHORA.

Squids. Shell (pen) a straight, chitinous plate, grooved towards the upper side and representing the proöstracon alone, sometimes with a conical rudiment of the phragmocone at the aboral end; fins usually rhombic or more or less triangular and usually at the aboral end of the body: 8 families.

Key to the families of *Chondrophora* here described:

a_1 Fins not at the end of the body.....1. Sepiolidae
a_2 Fins at the end of the body.
  b_1 Siphon with a valve.
    c_1 Tentacular arms without hooks.
      d_1 Eyes with a cornea.....2. Loliginidae
      d_2 Eyes naked, without cornea.....3. Ommastrephidae
    c_2 Tentacular arms armed with hooks.....4. Onychoteuthidae
  b_2 Siphon without a valve.....5. Cranchiidae

Family 1. SEPIOLIDAE.

Body short and wide; fins large, rounded, with a narrow base and near the middle of the body; tentacular arms retractile; eyes with a cornea; pen (shell) about half as long as the body and in its hinder half, or absent: 17 species.

1. Stoloteuthis Verrill. Body short, globose; head very large; arms united together by a broad web; tentacular arms with 8 or more rows of very small stalked suckers; upper arms hectocotylized; mantle united with head on back; pen absent: 1 species on the Atlantic coast.

S. leucoptera Verr. Butterfly squid (Fig. 956). Length of body 30 mm.; fins large, nearly as long as body, transparent, whitish; color brilliant, upper surface thickly spotted with orange brown; under surface brown and blue: Gulf of Maine, in 100 fathoms; rare.

Fig. 956
Stoloteuthis leucoptera (Verrill).

2. **Rossia** Owen. Like the above, but the mantle is not united with the head; pen small; both upper arms hectocotylized: 10 species, 3 in North Atlantic.

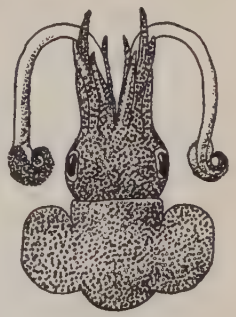

Fig. 957
Rossia sublevis (Verrill).

R. hyatti Verrill. Length of body 40 mm.; breadth 17 mm.; length of tentacular arms 40 mm.; length of longest sessile arms 18 mm.; 2 rows of suckers towards the base of each arm, distal portion with about 4 rows; color pinkish, spotted with purplish-brown above: Cape Cod and northwards, in 40 to 150 fathoms; rather common.

R. sublevis Verr. (Fig. 957). Length 46 mm.; breadth 22 mm.; length of tentacular arms 25 mm.; of longest sessile arms 22 mm.; 2 rows of suckers on entire arm; color pinkish, spotted, with purplish-brown above: Cape Cod and northwards, in 40 to 150 fathoms; commoner than the above.

Family 2. LOLIGINIDAE.

Body elongate; fins terminal; shell (pen) as long as the trunk and pointed; tentacular arms partially retractile, with 4 rows of suckers; other arms with 2 rows; fourth arm on left hectocotylized at tip; siphon attached to head and with a valve; eye with a cornea: about 50 species; littoral.

Loligo Lamarck. Calamaries. Body elongate; fins rhombic in shape, united behind: 31 species, cosmopolitan, 3 on the Atlantic coast.

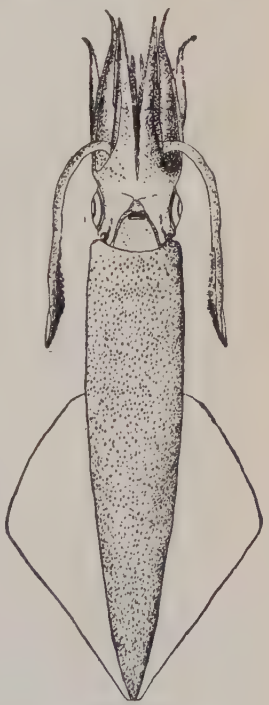

Fig. 958
Loligo pealei (Verrill).

L. pealei Lesueur (Fig. 958). Common squid. Body a flattened cylinder, pointed at the fin end; fins more than half the length of the

trunk; shell (pen) lanceolate, narrow; length 20 cm.; width 6 cm.; color dark grayish with reddish spots; eggs deposited in long cylindrical jelly masses, attached together at one end: Maine to South Carolina; very common.

L. pallida Verrill. Very similar to above; body thick, fins more than half the length of the trunk; color pale with few spots; length of body 20 cm.; length of fin 75 mm.: Long Island Sound.

Family 3. OMMASTREPHIDAE.

Body cylindrical, elongate; fins terminal, joined together and rhombic; arms usually short, with varying number of rows of suckers; eyes naked, without a cornea; siphons united by bands to the head; pen slender and small, with a hollow cone at the hinder end: cosmopolitan; about 25 species, mostly in the open ocean.

Key to the genera of *Ommastrephidae* here described:

a_1 Size small or moderate.....1. Ommastrephes
a_2 Size very large.....2. Architeuthis

1. **Ommastrephes** D'Orbigny. Sea arrows. Flying squids. Body elongate; arms with 2 rows of suckers; tentacular arms not retractile and with 4 rows of suckers; siphon valved: 13 species, 4 American.

O. illecebrosus (Lesueur) (Fig. 959). Fins about half as long as the trunk; length 30 cm.; width 3 cm.; length of fin 8 cm.; length of sessile arms 10 cm.; of tentacular arms 18 cm.; color deep blue, passing into red, spotted, sometimes pale: eastern end of Long Island Sound to Bay of Fundy and northwards, common north of Cape Cod; very swift in motion.

O. bartrami (Lesueur). More slender, elongated, and darker-colored than the above, with a relatively shorter caudal fin: Gulf stream, sometimes off the coast.

O. tryoni Gabb. Length 20 cm.: very common on the coast of California, where they are caught in great numbers by Chinese fishermen and dried for exportation to China.

2. **Architeuthis*** Steenstrup. Giant squids. Differs from the preceding genus in that an irregular group of small, smooth-rimmed suckers are on each tentacular arm, intermingled with rounded tubercles; suckers of sessile arms strongly denticulate; fins shaped like an arrowhead: 9 species, in the deep sea in all parts of the world, most of the specimens accurately known having been captured in the North Atlantic.

* See "The Colossal Cephalopods of the North Atlantic," by A. E. Verrill, Am. Nat., Vol. 9, p. 21, 1875.

A. princeps Verrill (Fig. 960). Length of body up to 6 m.; of the tentacular arms 11 m. and more; of the sessile arms 3 m.; of beak 12 cm.; diameter of suckers 30 mm., of the eyes 35 cm.: in the deep sea, thrown up occasionally on the coast of Newfoundland; the largest cephalopod.

Family 4. ONYCHOTEUTHIDAE.

Body cylindrical, fins terminal or lateral; tentacular arms very long and furnished with retractile hooks as well as suckers; shell lanceolate, with a terminal cone; eye naked, without a cornea: 23 species; pelagic.

Fig. 959

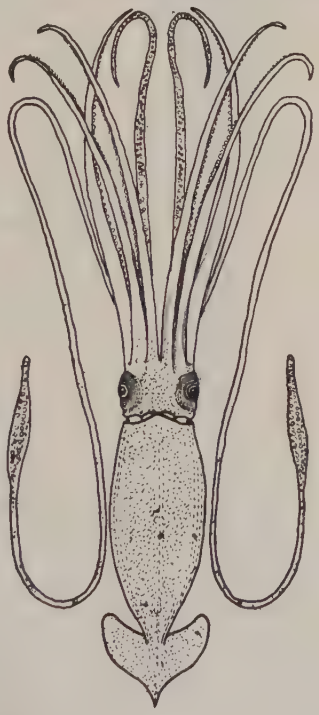

Fig. 960

Fig. 959—*Ommastrephes illecebrosus* (Verrill). Fig. 960—*Architeuthis princeps* (Verrill).

Onychoteuthis Lichtenstein. Body elongate; sessile arms without hooks and with 2 rows of non-denticulate suckers; tentacular arms, thick, with 2 rows of strong hooks, with a group of rounded suckers at their base: 10 species, 1 on the Atlantic and 1 on the Pacific coast.

O. banksi Leach. Head with 11 longitudinal ridges; fins rhombic, wider than long, about half the length of the body; length 15 cm.; color brownish, with blue around the eyes: in all seas; often common.

Family 5. CRANCHIIDAE.

Body cylindrical; head small, with large eyes, which are without cornea; sessile arms short; tentacular arms long and slender; shell lanceolate: 13 species.

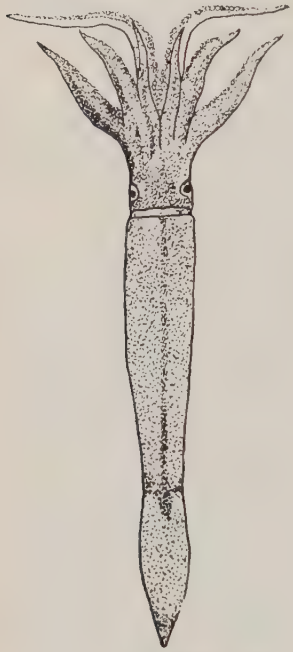

Fig. 961—*Loligopsis pavo* (Verrill).

Loligopsis Lamarck. Body elongate, attenuate behind, with large fins; siphons not valved: 8 species.

L. pavo (Lesueur). Peacock squid (Fig. 961). Body very long, being 1 m., including tentacles; fins about one-fourth the length of the body, rounded in outline; color red, spotted: Arctic seas, south to Cape Cod; very rare on our coasts.

Suborder 2. OCTOPODA.

Body more or less globose, generally without fins; 8 arms, with suckers usually sessile; no shell except in *Argonauta;* no nidamental glands: about 140 species, grouped in about 5 families.

Family 1. ARGONAUTIDAE.

Female with a thin, symmetrical, spiral shell, without septa, which is secreted by terminal expansions of the two upper arms and is used as an egg-case, which the animal can leave at will; male very small, with the third arm on the right hectocotylized: 1 genus; in all the warmer seas.

Argonauta L. Argonaut. Paper nautilus. With the characters of the family: 11 species, 1 on the Atlantic and 1 on the Pacific coast.

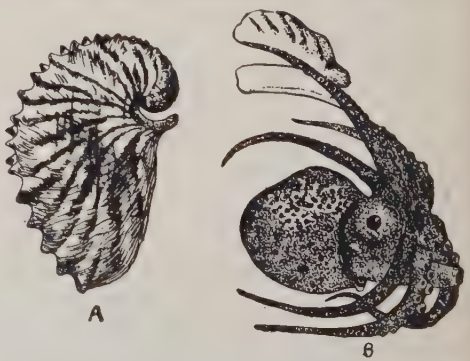

Fig. 962—*Argonauta argo.* A, shell; B, animal without shell (Verrill).

A. argo L. (Fig. 962). Shell whitish, ribbed, with 2 rows of sharp protuberances on the periphery, 20 cm. long; length of female 20 cm.; color whitish or yellowish with red dots; length of male 25 mm.: Atlantic Ocean, occasionally on the coast of the central and southern states.

Family 2. OCTOPODIDAE.

Devil-fishes. Head very large; arms elongated, webbed, similar; suckers in 2 rows and sessile; mantle united to the head by a broad, dorsal commissure; third arm on right hectocotylized: about 8 genera.

Octopus Lamarck. Sea polyp. Body round; arms long; no fins: 50 species; cosmopolitan; 2 species on the Pacific coast, 4 on the Atlantic.

O. bairdi Verrill (Fig. 963). Body short, thick, covered with small tubercles, 75 mm. long, 35 mm. wide, bluish-white in color, specked with brown; arms short, 10 cm. long, webbed a third of their length: common north of Cape Cod in rather deep water; Europe.

Fig. 963—*Octopus bairdi* (Verrill).

O. punctatus Gabb. Body ovate, 9 mm. long; length of arms 22 mm.; color red, spotted: common from Alaska to Lower California, in tide pools; it grows much larger in open water, where the length of the body may be 30 cm., and that of the arms 5 m.

PHYLUM 7.

ECHINODERMATA.*

Marine animals with a radially symmetrical, five-rayed body, with calcareous spicules or plates in the body wall, and a system of tubes extending throughout the body known as the ambulacral or water-vascular system.

External Form.—The larval echinoderm is typically a minute, bilaterally symmetrical animal (Fig. 964) which swims about actively in the surface waters of the sea; it goes through a complicated metamorphosis and is finally transformed into the radially symmetrical adult, which lives on or near the bottom, either creeping, or in some cases swimming, slowly about, burrowing in the sand or in the rocks, or permanently attached by a stalk to one place. The body of the adult is made up of ten principal divisions, which radiate from the main body axis like the spokes of a wheel (Fig. 965). These divisions are the five radii or rays (1) and the five interradii or interrays (2), which alternate with them. The main axis of the body passes between its two most important surfaces. These are the oral or under surface, in the center of which is usually the mouth (3), and the aboral or upper surface, which is opposite to it, and in most cases contains the anus (4). The relative length of its main axis determines the gen-

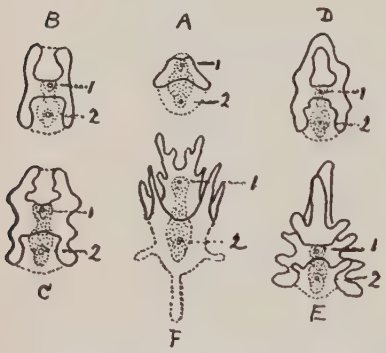

Fig. 964—Larvae of echinoderms (after J. Müller). A, youngest stage, common to all the classes; B and C, two stages of the auricularia (*Holothurioidea*); D and E, two stages of the bipinnaria (*Asteroidea*); F, a pluteus (*Echinoidea*). 1, mouth; 2, anus.

* See "Invertebrate Animals of Vineyard Sound," by A. E. Verrill, Rep. of U. S. Fish Com. for 1871. "Echinodermata," by W. N. Lockington, Stand. Nat. Hist., Vol. 1, 1888. "Echinodermen," by H. Ludwig and O. Hamann, Bronn's Klassen u. Ord., 2 Bd., 3d Abt., 1889-1904. "Distribution of the Echinoderms of Northeastern America," by A. E. Verrill, Am. Jour. Sci., Vol. 49, p. 127, 1895. "Echinoderms of the Woods Hole Region," by H. L. Clark, Bull. U. S. Fish. Com., Vol. 22, p. 543, 1902. "Les Echinodermes," by Delage et Hérouard, Traité de Zool. Coner, 1903. "Echinodermata," by E. W. MacBride, Camb. Nat. Hist., 1906. "Echinoderms of Connecticut," by W. R. Coe, Bull. No. 19, St. Geol. and Nat. Hist. Sur., 1912. "A Biological Survey of Woods Hole and Vicinity," by F. B. Sumner and others, Bull. Bur. Fisheries, Vol. 31, 1911.

eral shape of the body. In some echinoderms this axis is very short, as in the starfish, the oral and aboral surfaces are near together, and the body is flat and disc-shaped; in these animals the oral surface is

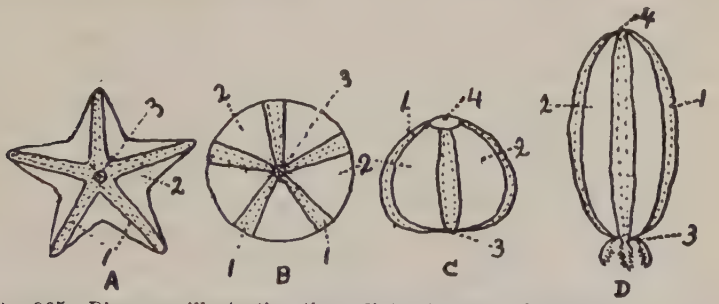

Fig. 965—Diagrams illustrating the radiate structure of echinoderms. A, starfish, oral aspect; B, sea urchin, oral aspect; C, sea urchin, lateral aspect; D, holothurian, lateral aspect (Boas). 1, radius; 2, interradius; 3, mouth; 4, anus.

the under one, on which the animal moves about, and the main body axis is perpendicular to the ground. In others the main axis is long and the body is consequently long and worm-like, as in holothurians; the oral surface, with the mouth, is not undermost in these animals, but is at what may be called its anterior end, and the animal lies with its main axis parallel with the ground. In crinoids the oral surface lies uppermost (Fig. 968), and in many of them a long stalk extends from the aboral surface attaching the animal to the sea bottom.

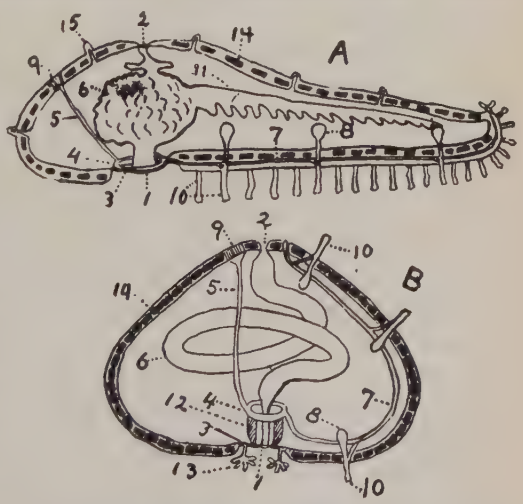

Fig. 966—Diagram of a starfish and sea urchin, showing the arrangement of certain of the organs. A, a section through the disc and one arm of a starfish; B, a section through a sea urchin (altered from Boas). 1, mouth; 2, anus; 3, peristome; 4, ring canal; 5, stone canal; 6, stomach; 7, radial canal; 8, ampulla; 9, madreporite; 10, ambulacral foot; 11, liver; 12, dentary body; 13, gill; 14, calcareous plates; 15, papula.

In starfishes, brittle-stars, and crinoids the radii are greatly elongated, forming five or more large arms, which radiate from a central disc (Fig. 965, A). Many echinoderms also show a decided tendency towards the development of a secondary bilateral symmetry and always move with a certain radius in advance (Fig.

989). Projecting from the surfaces of the radii into the surrounding water are soft, tubular structures known as the ambulacral appendages or podia, which are parts of the ambulacral system (Fig. 966, 10). In many echinoderms a sucker disc terminates each appendage; the animal attaches this to objects in the water and then by the muscular contraction of the appendage pulls itself slowly along; such appendages are called ambulacral or tube feet. Ambulacral appendages perform a variety of functions, however, besides that of locomotion; they may assist in the taking of prey and are also always, whether provided with sucker discs or not, important tactile, respiratory, and perhaps excretory organs. Spines also, sometimes controlled by muscles and sometimes not, as well as other special structures, project from the body of starfishes, sea-urchins, and brittle-stars.

Special sense organs are very poorly developed. Some starfishes, holothurians, and sea-urchins have pigment eyes, and most sea-urchins and some holothurians have static organs, but these and all other echinoderms must depend principally on their tactile sense for a knowledge of their environment.

The color of the body is in many echinoderms brilliant and varied, often being orange, red, or purple; some are quite transparent.

Internal Structures.—The body wall of echinoderms contains characteristic calcareous bodies (Fig. 966, 14). These are least developed among the holothurians, where they are minute spicules, which give a certain rigidity to the body wall, and are best developed in the sea-urchins, in which they consist of polygonal plates, forming a closed case. The body cavity is voluminous and contains the vegetative and reproductive organs. The alimentary tract is well developed and extends from the mouth to the anus (6). The ambulacral system is an extensive system of tubes, which are filled with a watery fluid containing blood or lymph corpuscles. The main part of the system is a ring-shaped canal or tube (4) which surrounds the œsophagus, and five radial canals (7) which spring from the ring canal and traverse the five radii. From these radial canals, and in some cases from the ring canal also, branch canals go off to the ambulacral appendages (10), which, as we have seen, project from the surface of the body into the water. Sac-like expansions of the branch canals called ampullae (8) are usually present. From the ring canal an additional vessel called the stone canal (5), because its walls usually contain minute calcareous bodies, passes, in starfishes, sea-urchins and brittle-stars, to the external surface of the body, where it opens to the outside through a perforated plate called the madreporite (9), and in holothurians and crinoids ends free in the body cavity. In crinoids and some holothurians more than one stone canal may be present. The purpose of the

stone canal is to introduce sea water (or the body fluid) into the ambulacral system. The fluid in it is, however, never pure sea water but always contains lymph bodies in the form of amœboid cells. Lymph glands occur in the ambulacral system of many starfishes in the form of small sacs called Tiedemann's vesicles, which spring from the wall of the ring canal. In many echinoderms there also arise from the ring canal elongated sacs known as Polian vesicles. These seem to serve chiefly as regulators of the pressure in the ambulacral system, but they may also give rise to the amœboid cells. An organ of somewhat problematical function called the axial organ, which surrounds the stone canal, without, however, opening into it, is also probably a lymph gland, and has, besides, a close relation to the reproductive organs; in most echinoderms this organ is itself surrounded by the axial sinus, a tubular portion of the body cavity.

The fluid in the ambulacral system is kept in circulation by means of cilia on the inner surface of the tubes, and muscle fibers in their walls; valves are present where the ambulacral feet join the branch canals.

There are two or three systems of nerves in the echinoderm body. These are (1) the superficial oral system, consisting of a ring nerve around the mouth or the œsophagus, and five radial nerves which pass along the five radii; (2) the deeper oral system which accompanies the superficial system; and (3) the apical system which is confined to the aboral body wall. The first of these systems is present in all echinoderms and innervates the ambulacral system and the digestive canal. The second is wanting in crinoids and certain sea-urchins; the third is especially prominent in crinoids, but is wanting in holothurians.

The general surface of the body, including the ambulacral appendages, plays the greatest part in the performance of the functions of respiration and excretion. In starfishes and sea-urchins, where the surface is ciliated, its importance in this particular is increased; the papulae of the former and the peristomial gills of the latter still further enlarge its functional area. Most holothurians have special respiratory organs, and the bursae of brittle-stars may function as such.

The body cavity is not a single space but a complex system of spaces and canals, some of which are often cut off from the rest, and which contain a circulatory fluid similar to that in the ambulacral system. There is one principal space, which may be called the body cavity proper, containing the greater part of the viscera, and small spaces and canals which extend to every part of the body and surround the principal organs. The most important of these canals are the radial blood vessels, which consist of a ring vessel and five radial vessels, following the ambulacral canals and the radial nerves. No heart is present, and the blood fluid is kept in

circulation by the cilia which line the inner surface of the spaces and vessels.

The sexes are separate in the majority of echinoderms, the males and females being more or less alike in appearance. The genital organs are simple in structure. Except in the holothurians and some sea-urchins, they consist of five gonads or pairs of gonads, which open separately to the outside. In the holothurians, they consist of a branched gonad which opens to the outside near the mouth; this gonad may be homologous to the axial organ of other echinoderms. No accessory genital glands or organs are present among echinoderms, and the sperm and ova are usually thrown into the surrounding water, where fertilization takes place.

Echinoderms have great regenerative powers; an arm broken off is replaced, and a holothurian may regenerate its digestive tract and other viscera if these are voided when the animal is irritated. Certain starfishes and brittle-stars reproduce asexually, by transverse division.

Distribution and Habits.—Echinoderms are inhabitants of the sea bottoms. They are found in all parts of the globe, the various species ranging from the shore line to the greatest depths. A few forms can swim, but the greater number creep slowly about, feeding on small animals and plants, organic matter in the sand and mud, or seaweeds.

History.—Leuckart, in 1847, first recognized the *Echinodermata* as one of the main subdivisions of the animal kingdom. The name originated with Klein, who, in 1734, applied it to the sea-urchins. Lamarck added the starfishes and Cuvier the holothurians to the group, which formed a class under the *Zoophyta* or *Radiata.* Leuckart's great service consisted in showing that Cuvier's *Radiata* formed an assemblage of animals which are without natural relationships and in splitting it into the *Cœlenterata* and *Echinodermata,* the former being very primitive animals without a distinct body cavity or a digestive tract, both of which are possessed by the latter.

The *Echinodermata* contain about 4,000 species, grouped in five classes.

Key to the classes of *Echinodermata:*

a_1 Arms present.
  b_1 Arms with small branches called pinnules; oral surface directed upwards. ..... 1. CRINOIDEA
  b_2 Arms without pinnules; oral surface directed downwards.
    c_1 Oral surface of arm with a deep longitudinal (ambulacral) groove. ..... 2. ASTEROIDEA
    c_2 Ambulacral grooves absent ..... 3. OPHIUROIDEA
a_2 Arms absent.
  b_1 Body covered with movable spines; no oral tentacles ..... 4. ECHINOIDEA
  b_2 Body without spines; oral tentacles present ..... 5. HOLOTHURIOIDEA

Class 1. CRINOIDEA.

Sea-lilies. Feather-stars. Echinoderms which, either throughout life or during their youth alone, are attached by a stalk to the sea bottom. The body of the typical crinoid is made up of three parts, the disc or calyx, the arms, and the stalk. The calyx is more or less cup-shaped and forms the central mass of the body. Its oral surface, with the mouth, is directed upwards; near the mouth and raised above the surface in an interradius is the anus. The aboral side is directed downwards and is attached to the stalk when this is present. In some crinoids the stalk bears whorls of jointed appendages called cirri. In most living crinoids the stalk is wanting in the adult animal.

The arms are either five or ten in number, and often branch dichotomously. They bear small alternating branches called pinnules which give them a feathery appearance. Five ambulacral grooves radiate from the mouth to the arms, and pass along their oral surface, branching with them, extending to the tips of the pinnules. These grooves are lined with cilia, which create a current running towards the mouth, to which they aid in bringing food. Ambulacral appendages are present along the edges of the grooves, which are tactile, respiratory, and excretory in function. The general surface of the body is not ciliated. No special sense organs are present.

Internal Organs.—The calcareous skeleton of crinoids is extensively developed. The aboral wall of the calyx contains two groups of polygonal plates which fit together closely and are often fused; these are the basals (Fig. 968, 1) and the radials (2). The former are at the end of the stalk, occupying interradial areas; they are normally five in number, but may be reduced by fusion, or increased to ten by the addition of five infrabasals in the radial areas between the basals and the stalk.

The radials are in the radial areas and lie above the basals, one or more rows of them being present; interradials are present in some species. The oral body wall in *Holopus* and other primitive crinoids contains five large oral plates; in most crinoids, however, a number of small plates is here present, or there may be no plates at all. A row of large circular plates called brachials is present in the arm, which join the radials.

The stalk contains a succession of disc-like plates placed one on top of another; the cirri are similarly jointed.

The body cavity occupies the calyx, and extends through the arms to the tips of the pinnules and through the stalk and cirri. In the calyx it contains a network of connective tissue fibers which are often calcified.

* See "Report on the Crinoidea," by F. H. Carpenter, Reports of the Challenger, Vol. 26, 1888.

The body cavity contains a blood fluid mixed with sea water, which is admitted through ciliated pores in the oral wall of the calyx.

The mouth opens into the tubular digestive canal, which runs once round the main axis of the body cavity and then opens to the outside through the anus. No digestive glands are present, but certain interradial diverticula of the intestine in *Antedon* may have a glandular function.

The ambulacral system consists of a ring canal around the mouth and five radial canals which branch with the arms and are continued in the pinnules. The ambulacral appendages along the edges of the ambulacral groove are without terminal suckers and ampullae. A number of stone canals, which lack calcareous bodies in their walls, leave the ring canal and end free in the body cavity. Five groups of ambulacral tentacles also spring from the ring canal and surround the mouth.

The superficial oral nervous system, consisting of an oral nerve ring and a radial nerve in each arm, is situated just beneath the outer epithelium; an apical system is also present, consisting of a nerve capsule in the aboral calcareous plates and large radial nerves which run through the brachials into the arms. The reproductive organs, the ovaries or testes, extend throughout the arms and into the pinnules, where they become ripe, and through minute pores of which the ova or sperm are extruded. The five gonads are usually joined with an organ called the genital stolon, which lies in the axis of the calyx and is homologous to the axial organ of other echinoderms. The sexes are separate.

Distribution and Habits.—The stalked crinoids are deep-sea forms, and most numerous in East Indian waters, but are also found in nearly all oceans; they constitute about one-fifth of living crinoid species. The *Antedonidae* and *Comasteridae* are not stalked as adults, and are also commonest in East Indian waters, varying from the shallow waters along the shores to great depths, but are also found, and often plentifully, in almost all seas; they do not occur, however, in the shallow waters of New England. The stalked forms may be rooted to the bottom, but it is likely that the stem is occasionally broken accidentally or perhaps by the animal itself and that it then moves about by means of the arms. *Isocrinus* is perhaps never permanently rooted, but anchors itself temporarily by its cirri, and possibly moves about at will. The *Antedonidae* and *Comasteridae* are found among rocks and coral colonies and move about slowly, swimming by means of their arms.

History.—*Antedon,* which has always been the best known crinoid, was usually classed with starfishes by the earlier zoologists. J. S. Miller, in 1821, first organized the group under the name *Crinoidea,* and E. Forbes, in 1841, raised it to the dignity of an independent class.

The *Crinoidea* contain nearly 500 living species, grouped in a dozen or more families; about 2,000 fossil species are known.

Key to the families of *Crinoidea* here described:

a_1 Sessile crinoids (as adults).
  b_1 Calyx attached directly by its base.....1. HOLOPODIDAE
  b_2 Calyx attached by a long stalk.
    c_1 Stalk without or with very few cirri.....2. BOURGUETICRINIDAE
    c_2 Stalk with cirri.....3. PENTACRINIDAE
a_2 Crinoids which are not sessile (as adults).
  b_1 Pinnules cylindrical or somewhat flattened, with very long segments. 4. ANTEDONIDAE
  b_2 Pinnules, at least the lower, more or less prismatic, with short segments. 5. COMASTERIDAE

FAMILY 1. HOLOPODIDAE.

All the aboral plates of the calyx fused together; calyx joined directly with the sea bottom, no stalk being present; 10 short thick arms present, which curl inwards: 1 genus.

HOLOPUS D'Orbigny. With the characteristics of the family: 1 species.

H. rangi D'Orb. Height 4 cm.: in the Caribbean Sea; rare.

FAMILY 2. BOURGUETICRINIDAE.

Calyx slender, with 5 basals and 5 radials often united, and with 5 or 10 arms; stalk long, with very few or no cirri: 1 living genus.

RHIZOCRINUS Sars. Calyx elongate; 5 slender arms with long pinnules; no cirri except on root of stalk: 15 to 20 species.

R. lofotensis Sars. Arms with 30 to 40 segments, 8 cm. long; stalk 7 cm. long: in Atlantic Ocean, from 80 to 1,900 fathoms.

FAMILY 3. PENTACRINIDAE.

Calyx small; 5 arms, each dichotomously divided 1 to 10 times, with small pinnules; stalk long, with long cirri; no root: 4 to 5 living genera.

ISOCRINUS Von Meyer. Calyx with 5 basals; arms divided 3 to 5 times; stalk often very long, and more or less distinctly pentamerous in cross section: 3 species in the West Indian region.

I. asterias (L.) (Fig. 967). Length of stalk up to 48 cm., of the cirri 7 cm., of the arms 10 cm.: West Indies, in 80 to 300 fathoms.

FAMILY 4. ANTEDONIDAE.

Crinoids which have a stalk and are sessile only as young animals, the adult having shed the stalk, except the first segment or the first few segments which fuse together and bear cirri and are called the "centrodorsal;" 5 to 20 or more long arms, on which are pinnules: several

genera with more than a hundred species; in almost all seas from shallow water to 2,900 fathoms, among rocks or hydroid or coral colonies or in algae, climbing about actively by means of their arms and cirri or swimming about slowly.

Antedon Fréminville. Mouth central and ambulacral grooves equal in length; pinnules smooth, one or more of the proximal elongated and flagellate; centrodorsal hemispherical or nearly discoidal, with 10 to 30 cirri: 35 species.

Fig. 967

Fig. 968

Fig. 967—*Isocrinus asterias* (Leunis). Fig. 968—*Antedon tenella*—a young, attached individual (Verrill). 1, basal; 2, radial; 3, brachial.

A. tenella (Retzius) (*A. dentata* Say) (Fig. 968). Ten arms; centrodorsal with 25 to 30 cirri, each with 10 to 16 segments; diameter 6 cm.: Atlantic coast, in 35 to 600 fathoms, from New Jersey northwards.

Family 5. COMASTERIDAE.

Similar to the *Antedonidae,* but differing in that the mouth is excentric, the ambulacral grooves are of unequal length, the proximal pinnules are serrated, and the centrodorsal is discoidal with few or no cirri: a dozen genera and numerous species; in all warm seas, chiefly in shallow water.

1. **Neocomatella** A. H. Clark (*Comatula* Lamarck; *Actinometra* J. Müller). Outer segments of cirri with slight dorsal processes; arms more than 10: 1 species.

N. alata (Pourtalès). Twenty arms present; centrodorsal with about 30 cirri in 2 irregular rows, each with 15 to 18 segments: West Indian waters, from 78 to 310 fathoms.

2. **Comactinia** A. H. Clark. Segments of cirri without dorsal processes; 10 arms present: 3 or 4 species; in West Indian waters.

C. meridionalis (E. C. and A. Agassiz). Length and stoutness of arms variable; segments of genital pinnules very short: Beaufort, N. C., and southwards, in 12 to 100 fathoms.

Class 2. ASTEROIDEA.*

Starfish. Echinoderms in which the radii are more or less elongated so that the body has the form of a five-armed star (Fig. 965, A). In some of them the number of arms is normally greater than five, and many abnormal individuals are found with more or sometimes less than this number. The oral surface is directed downwards and on it the animal rests and moves about; the aboral surface is directed upwards. Surrounding the mouth is a membranous area called the peristome (Fig. 966, A, 3). The main axis of the body is short and extends from the mouth in the middle of the oral to the middle of the aboral surface: the anus has an excentric position in this surface.

Extending from the peristome along the oral surface of each arm is the median ambulacral groove, from the walls of which either two or four rows of ambulacral feet project into the surrounding water (10). On the aboral surface in an interradius is the madreporite (9), the external opening of the ambulacral system.

Fig. 969—A and B, pedicellariae (Leunis); C, a paxilla (Ludwig).

The external epithelium is ciliated. Spines or tubercles appear on the surface of all starfishes; some of these especially along the edges of the ambulacral grooves are movable. Minute pincer-like organs called pedicellariae (Fig. 969, A and B), which are modified spines, are usually present; they may be either sessile or pedunculate (stalked), and their jaws are either straight or crossed like scissors. Paxillae (C), also modified spines, are present in some groups, each paxilla being a thick calcareous rod, the summit of which is covered with minute spines. Short finger-like projections of the body wall called papulae (Fig. 966, 15) also appear, especially on the

* See "North American Starfish," by A. Agassiz, Mem. Mus. Comp. Zool., Vol. 5, 1877. "Report on the Asteroidea," Zoology of the Challenger, Vol. XXX, by W. P. Sladen, 1889. "Asteroidea," by A. E. Verrill, Amer. Jour. Sci., Vol. 49, 1895. "Revision of Certain Genera and Species of Starfish," by A. E. Verrill, Trans. Conn. Acad., Vol. 10, p. 145, 1899. "Asteroidea of the North Pacific and Adjacent Waters," by W. K. Fisher, Bull. U. S. N. M., 1911.

aboral surface, which are of importance in respiration and excretion. A red eye spot is present at the tip of each arm, but with this exception special sense organs do not occur.

Internal Structure.—The calcareous plates which support the body are of various sizes and joined with one another by muscles and connective tissue fibres. The most regularly arranged of them are the ambulacral plates, two rows of narrow calcareous rods which form the roof of the ambulacral groove; between these plates are the ambulacral pores.

The mouth (1) is a small opening in the middle of the peristome. From it a short œsophagus leads to the large stomach (6), which, with its folded walls, fills the disc. Joining the aboral portion of the stomach are the five pairs of extensively branched liver sacs which lie in the arms. A short, slender rectum passes from the stomach to the anus (2) and may send off a small branched cæcum; anus, rectum, and cæcum are apparently all rudimentary structures, and the anus and cæcum may be absent. The ring canal (4) and the radial canals of the ambulacral system are extra-skeletal in position, the former lying at the margin of the peristome and the latter in the middle line of the ambulacral grooves. Paired branches go from the radial canals to the ambulacral appendages, which, except in three or four families, possess terminal sucker discs and are used for locomotion. One or two rows of these are present on each side of the radial canal; from each foot a small sac called an ampulla (8) extends through the ambulacral pore into the body cavity, the function of which is to aid in extending the foot. The walls of the ampulla, as those of the foot, are muscular and by their contraction the ambulacral fluid is forced into the foot. The terminal end of each radial canal projects freely into the water at the tip of the arm. Two kinds of glandular sacs may extend from the ring canal through pores into the body cavity, which furnish lymph cells to the ambulacral fluid; those of most general occurrence are the Tiedemann's vesicles; the others and larger ones are the Polian vesicles. The ring canal is joined with the madreporite by the stone canal (5).

Special respiratory and excretory organs are not present, the ciliated external surface of the body with the papulae and ambulacral appendages performing the functions of such organs.

The most important circulatory vessels are a ring vessel and five radial vessels which lie just beneath the main ambulacral canals; they are in open connection with the body cavity. The superficial oral nervous system is epithelial and extra-skeletal in position; each radial nerve ends at the tip of the arm with an eye. The other nerves are intra-skeletal and are not strongly developed.

The sexes are, with rare exceptions, separate. The testes and ovaries look much alike and consist of five pairs of racemose glands at the base of the arms, which open to the outside through minute pores in the interradii. Adjoining the stone canal is the cylindrical axial organ enclosed in the axial sinus, a portion of the body cavity. An extension of the axial organ forms a ring around the aboral side of the body cavity, from which a strand goes to each reproductive gland. The axial sinus follows this extension and also finally encloses the glands themselves. The larval starfish is either a bipinnaria or a brachiolaria. In some starfishes the female forms a brood sac by bending the arms together, in which the eggs are sheltered.

Distribution and Habits.—Starfish are common animals throughout the world, being found in all seas from tide lines to very great depths. They move slowly about on the bottom by means of their ambulacral feet and also to some extent by the movements of their arms, often in schools, devouring the mollusks and crustaceans they meet in their path. They are important enemies of the oyster fisheries. A starfish kills its prey by wrapping its arms about it and everting its stomach over it (Fig. 970), and slowly digesting its soft parts. Those which have no suckers on the tube feet, however, can not do this and are not carnivorous but feed on minute organisms which they swallow. Starfish possess great regenerative powers and can replace lost arms.

Fig. 970—Starfish feeding (Cambridge Natural History).

History.—Starfishes were well known to Aristotle and also to the medieval writers on animals. The scientific knowledge of them begins with Linck in 1733, whose work was a standard until the time of Cuvier. In 1816 appeared Tiedemann's comprehensive description of the anatomy of the animals, and this and Müller and Troschel's classification (1842) laid the foundation of our present knowledge of the group. The bipinnaria larva was discovered by M. Sars in 1829. The modern classification is based upon that of Perrier (1875), and of Sladen (1889).

The class contains 3 orders and about 1,000 species.

Key to the orders of *Asteroidea:*

a_1 Starfishes with prominent contiguous marginal plates along the sides of the arms and with 2 rows of ambulacral feet in the arm. 1. PHANEROZONIA

a_2 Starfishes usually with long arms and without prominent marginal plates; aboral body wall spiny; ambulacral feet with suckers.

b_1 Pedicellariae very rare or absent and not pedunculate.....2. SPINULOSA

b_2 Pedicellariae present and pedunculate.....3. FORCIPULATA

Order 1. PHANEROZONIA.

Either 1 or 2 rows of large marginal plates along the sides of the arms (Fig. 971), these plates being in contact with one another and giving the arm a definite margin; 2 rows of ambulacral feet in each arm; pedicellariae often wanting, and when present, sessile: 8 families.

Key to the families of *Phanerozonia* here described:

a_1 Aboral wall membranous, and covered with paxillae or spines; feet conical; suckers inconspicuous or absent.
b_1 Arms long; feet without suckers; paxillae present....1. Astropectinidae
b_2 Body usually pentagonal; epiproctal projection on aboral surface. 2. Porcellanasteridae
a_2 Aboral wall not membranous; body often pentagonal; feet with sucking discs.
b_1 Aboral wall with closely fitting plates, mosaic-like.....3. Goniasteridae
b_2 Plates of aboral wall form a reticulum.
c_1 Body covered with a smooth, thick skin.....5. Asteropidae
c_2 Body not covered by a thick skin.....4. Oreasteridae

Family 1. ASTROPECTINIDAE.

Flattened starfishes with long, slender arms, with a membranous aboral wall covered with paxillae (Fig. 969, C), with very large marginal plates (Fig. 971, 2), which may carry long spines, with conical ambulacral feet which lack the sucking disc, and usually without anus: 9 genera, with more than 100 species.

1. Astropecten Gray. Two rows of marginal plates, the lower row with many spines, the upper row with granules or spines; no pedicellariae: 60 species, in all parts of the world, mostly littoral.

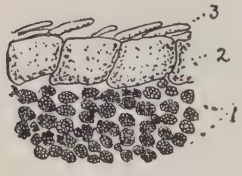

Fig. 971—Small portion of the aboral margin of an arm of *Astropecten californicus* (Fisher). 1, paxillae; 2, upper marginal plates; 3, spines on the lower marginal plates.

A. articulatus (Say). Each upper marginal plate near tip of arm with a small blunt tubercle; size 20 to 25 cm.: New Jersey southwards, from the shore to 25 fathoms; often common.

A. duplicatus Gray. Upper marginal plates with erect, conical spines; size 15 to 20 cm.: North Carolina southwards; common in 6 to 15 fathoms.

A. californicus Fisher (Fig. 971). Upper marginal plates without spines or tubercles; size 12 to 18 cm.: coast of California, in 10 to 240 fathoms; common in Monterey Bay.

2. Luidia Forbes. Only one row (the lower) of marginal plates; pedicellariae usually present: 25 species, 10 in the Atlantic.

L. clathrata (Say). Aboral surface with crowded paxillae; arms much flattened; disc small; marginal plates narrow, 50 or more to an arm; size 20 to 30 cm.: New Jersey to Florida; often very common.

L. foliolata Grube. Similar to above, but with heavier and more spines on oral surface; size 30 to 50 cm.: Pacific coast from Alaska to Mexico, below low-water mark to 190 fathoms; often common.

L. senegalensis (Lamarck). Similar to the above, but with 9 arms; size 30 to 35 cm.: Florida and the West Indies; west coast of Africa.

FAMILY 2.
PORCELLANASTERIDAE.

More or less pentagonal starfishes with a membranous aboral wall covered with paxillae, in the middle of which rises a tube-like epiproctal projection; anus wanting; 2 rows of thin porcelain-like marginal plates without spines; between certain of these plates occur vertical rows of thin folds of the integument called cribriform organs: 25 species.

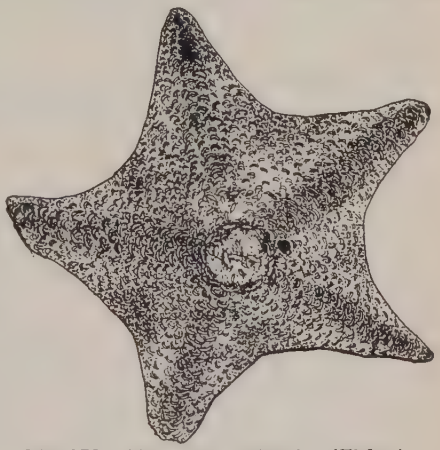

Fig. 972—*Ctenodiscus crispatus* (Fisher).

Ctenodiscus Müller and Troschel. Body stellate or pentagonal; paxillae on the aboral body wall: 1 species.

C. crispatus (Retzius) (Fig. 972). Size 7 to 10 cm.; form of body very variable, from pentagonal to stellate: circumpolar, ranging southwards to California and Cape Cod, from shallow water to 1,000 fathoms; often common off New England; Panama.

Fig. 973
Hippasteria pharygiana
(Verrill).

FAMILY 3. GONIASTERIDAE.

Flattened, usually pentagonal starfishes with 2 rows of very large marginal plates; plates in the aboral wall forming a mosaic, sometimes with paxillae: 40 genera.

1. **MEDIASTER** Stimpson. Upper marginal plates separated by paxillae; aboral plates with paxillae: 6 or more species.

M. æqualis Stimp. Papulae in twos and threes; color in life, bright red; size 10 to 15 cm.: Alaska to Lower California, in 9 to 167 fathoms.

2. **HIPPASTERIA** Gray. Principal skeletal plates each with a central tubercle; marginal plates with tubercular spines: 5 species.

H. pharygiana (Parelius) (Fig. 973). Size 15 to 20 cm.; upper surface bright red in life: north of Cape Cod, in 20 fathoms or more.

Family 4. OREASTERIDAE.

Thick-bodied starfishes with small marginal plates, and a reticulate arrangement (Fig. 974 B) of aboral plates: 10 genera.

Oreaster Müller and Troschel (*Pentaceros* Linck). Body very regularly star-shaped, with short arms and large central disc; plates with tubercles: 40 species, which are all littoral and subtropical or tropical.

O. reticulatus (L.) (Fig. 974). Diameter 30 to 40 cm.; body very thick: South Carolina and southwards, in shallow water.

Fig. 974—*Oreaster reticulatus* (Tennent). A, outline of body; B, aboral surface of arm.

Family 5. ASTEROPIDAE.

Starfishes whose body is covered by a thick, smooth skin, concealing the underlying skeleton: 7 genera.

Dermasterias Perrier. Body stellate and thick; no spines on the marginal or aboral plates: 1 species.

D. imbricata (Grube). Size 15 to 20 cm.: on rocks in shallow water: Alaska to Monterey, California; common.

Order 2. SPINULOSA.

Arms usually long and without prominent marginal plates; aboral body wall spiny and usually with a more or less reticular or imbricated skeleton; ambulacral feet with sucking discs; pedicellariae rare or absent and not pedunculate: 5 families.

Key to the families of *Spinulosa* here described:

a_1 Mouth plates small; ambulacral groove narrow.
  b_1 Aboral skeleton composed of imbricating scales.....1. Asterinidae
  b_2 Aboral skeleton reticular.....2. Echinasteridae
a_2 Mouth plates large; ambulacral groove wide.
  b_1 Usually more than 5 arms.....3. Solasteridae
  b_2 Five arms present.....4. Pterasteridae

Family 1. ASTERINIDAE.

Starfishes whose arms are joined by interradial expansions of the disc, with small marginal plates and with aboral plates usually imbricated: 10 genera.

Asterina Nardo. Body flattened, pentagonal or star-shaped: 32 species, in all seas, and all littoral.

A. folium Lütken. Aboral plates, each with 3 or 4 minute spines; size 5 cm.; color variable, often blue or greenish: Florida and West Indies; common on under side of rocks.

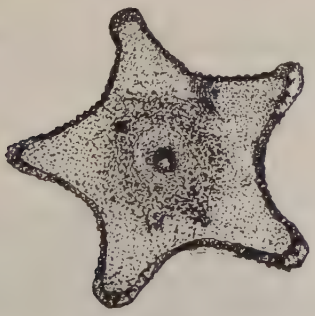

Fig. 975

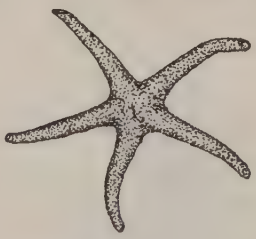

Fig. 976

Fig. 975—*Asterina miniata* (Fisher). Fig. 976—*Henricia sanguinolenta* (Clark).

A. miniata (Brandt) (Fig. 975). Aboral plates granular; size 6 to 10 cm.; color variable, but commonly red or yellow: Alaska to Lower California; one of the commonest low-tide species.

Family 2. ECHINASTERIDAE.

Starfishes with long, slender arms; feet in 2 rows; pedicellariae wanting; skeleton reticulate and formed of small imbricating plates: 10 genera.

1. **Henricia** Gray (*Cribrella* Lütken). Disc small; arms long and cylindrical; aboral plates form a very fine network with small meshes and numerous minute spines: 20 species; in northern seas.

H. sanguinolenta (O. F. Müller) (Fig. 976). Body bright red, purple, lavender, or yellow above and yellowish below; diameter 7 to 10 cm.: common from Greenland to Long Island Sound, ranging as far south as Cape Hatteras, from low-water mark to 200 fathoms; Pacific coast; Europe; Asia.

2. **Echinaster** Müller and Troschel. Arms long and cylindrical; meshes of aboral skeletal network rather large, with coarse, scattered spines: 20 species; littoral.

E. spinulosus Verrill. Disc rather small; color dark violet; size 10 cm.: common on the Florida coast, ranging north to Cape Hatteras or perhaps New Jersey.

Family 3. SOLASTERIDAE.

Arms long and slender and often more than 5 in number; aboral plates reticular, and bearing paxillae; 2 rows of feet and no pedicellariae: 6 genera, mainly in shallow water in temperate seas.

Solaster Forbes. Rays 7 to 14; aboral plates form a fine network with small meshes: 12 species.

S. endeca (L.). Purple sun-star (Fig. 977). Arms 7 to 13, usually 9 to 11 in number, with 2 rows of marginal plates; color reddish-purple

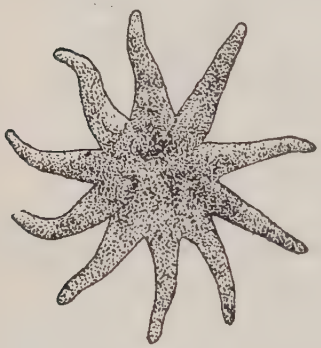

Fig. 977

Fig. 978

Fig. 977—*Solaster endeca* (Clark). Fig. 978—*Solaster papposus* (Fisher).

above; size 20 to 35 cm.: common from Cape Cod northwards, from low-water mark to 150 fathoms; Pacific coast; Europe.

S. papposus (L.). Common sun-star (Fig. 978). Arms 8 to 14, usually 10 or 11, with 1 row of marginal plates; color red or variegated; aboral network with larger meshes than in *S. endeca:* Cape Cod northwards, being common north of Casco Bay; Pacific coast; Europe.

Family 4. PTERASTERIDAE.

Starfishes with a large disc and short, thick arms; aboral surface covered with a skin which passes over the spines, enclosing a brood chamber; 2 or 4 rows of feet and no pedicellariae: 10 genera.

Pteraster Müller and Troschel. Aboral skin with a large central opening into the broad chamber, provided with valves; oral surface also covered with a similar skin: 28 species.

P. militaris (O. F. Müller) (Fig. 979). Arms short and thick; disc thick and arched; under side flat; diameter 9 cm.: circumpolar, south to Cape Cod and Washington, in 10 to 350 fathoms; Europe.

Fig. 979
Pteraster militaris (Leunis).

Order 3. FORCIPULATA.

Pedicellariae pedunculate, with either crossed or straight jaws; spines conspicuous; aboral skeleton reticular: 7 families.

Key to the families of *Forcipulata* here described:

a_1 Arms not sharply set off from the central disc.
b_1 Aboral skeletal plates almost contiguous.....1. Stichasteridae
b_2 Aboral skeletal plates from a reticulum.....2. Asteriidae
a_2 Arms sharply set off from central disc.....3. Brisingidae

Family 1. STICHASTERIDAE.

Starfishes with long, slender arms; aboral plates large and in longitudinal rows; 4 rows of feet: 4 or 5 genera.

Stichaster Müller and Troschel. Numerous spines on each side of the ambulacral grooves: 10 species.

A. albulus (Stimpson). Diameter of disc 2 to 3 cm.; 6 cylindrical rays, usually in 2 groups, 3 long and 3 short ones: Cape Hatteras (deep water), to the Arctic Ocean, low-water mark to 200 fathoms; often common.

Family 2. ASTERIIDAE.

Starfishes with usually a small disc and 5 to 12 or more arms; aboral plates with a reticulate arrangement and bearing spines; pedicellariae with straight and crossed jaws; 4 rows of feet: about 10 genera.

Asterias L.* Usually 5 arms present; 1 or more rows of movable spines on each side of the ambulacral groove; pedicellariae with crossed jaws around the base of the spines and with straight jaws among the papulae: numerous species; in shallow water in most seas, being commonest in temperate zones, and especially abundant and reaching very large size on the North Pacific coast of America.

A. forbesi (Desor) (*A. arenicola* Stimpson; *Asteracanthion berylinus* A. Agassiz). Common star (Fig. 980). Rays stout and tending to be blunt and cylindrical; spines rather few and coarse; madreporite bright orange; color very variable, being oftenest greenish-black; diameter 16

* See "Natural History of the Starfish," by A. D. Mead, Bull. U. S. Fish. Com. for 1899, p. 203, 1900.

cm. and more: common from Cape Cod southwards, less common or rare northwards to Maine, from the shore to 30 fathoms.

A. vulgaris Verrill (*Asteracanthion pallidus* A. Ag). Purple star (Fig. 981). Rays flattened and tending to be pointed; spines numerous, tending to form a noticeable median longitudinal row on the aboral sur-

Fig. 980

Fig. 980—*Asterias forbesi* (Clark).

Fig. 981

Fig. 981—*Asterias vulgaris* (Clark).

face of each arm; madreporite pale yellow; color very variable, but generally some shade of purple; diameter 15 to 40 cm.: common from eastern end of Long Island northwards, from the shore to 300 fathoms, ranging in deep water as far south as Cape Hatteras.

A. littoralis (Stimp.). Body thick, with very broad rays; color olive green; diameter 4 to 5 cm.; 2 rows of ambulacral spines: Casco Bay to Cumberland Gulf, in shallow water, often very common on fucus.

A. tenera Stimp. (Fig. 982). Arms cylindrical, slender, and tapering; skeleton firm, with numerous spines; madreporite small and nearly white; color varying from purplish-pink to nearly white; diameter 5 to 8 cm.: from Nova Scotia to New Jersey, in 10 to 85 fathoms, often common.

Fig. 982—*Asterias tenera* (Clark).

A. ochracea Brandt. Aboral plates very extensively developed, with only small holes between them; a prominent median ridge present on each arm; body very large and heavy, 60 to 70 cm. across, with arms 6 to 8 cm. in vertical diameter at base; color violet: one of the commonest starfishes on the Pacific coast, ranging from Alaska to San Diego.

Family 7. BRISINGIDAE.

Disc small and circular; arms 8 to 18 in number, long and round and set off from the disc like those of brittle-stars; feet in 2 rows; numerous pedicellariae: 6 genera, all of the species of which live in the deep sea.

Odinia Perrier. Disc with papulae on the upper surface; arms very fragile: 6 to 8 species.

O. americana (Verrill). Rays 20 in number, about 35 cm. long; color bright orange-red: New England coast, in 175 to 400 fathoms; rare.

Class 3. OPHIUROIDEA.*

Brittle-stars. The brittle-stars resemble the starfish in form, but the five rays are greatly elongated and form slender, cylindrical arms, which are sharply set off from the central disc and possess no ambulacral groove. Two rows of ambulacral appendages project from their oral surface into the water, but these lack terminal suckers and hence are not locomotory organs: the animal progresses by the snake-like movements of its arms. As in the starfish, the oral surface, with the mouth in its middle, is directed downwards, and the main body axis is very short. The mouth is a complex star-shaped opening bounded by characteristic skeletal pieces (Fig. 983); an anus is not present. The madreporite (3) is in the oral wall in an interradius. At the base of each arm is a pair of slits (1) which open into a pair of pouches called the genital bursae; in *Ophioderma* each slit is in two parts. These organs are possibly respiratory in function and are also the receptacles of the genital products.

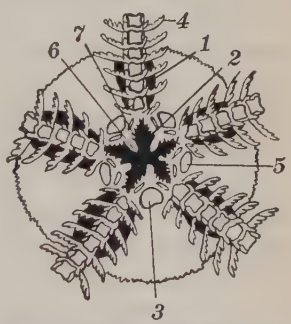

Fig. 983—Oral surface of the disc and the base of the arms (Coe). 1, genital bursa; 2, mouth; 3, madreporite; 4, arm spine; 5, buccal plate; 6, jaw; 7, oral papillae.

The external surface is not ciliated; pedicellariae are not present; spines usually project from the sides of the arms, and spines, scales, or granules are present on the disc. No special sense organs are present. In most species the number of arms is five, but there are six normally in some, and in others, seven or eight. In most of the *Astrophytidae* they are more or less branched.

Internal Structure.—The calcareous skeleton is usually well developed. The upper wall of the disc is flexible and contains a large num-

* See "Report on the Ophiuroidea," by T. Lyman, Challenger Reports, Vol. 5, 1876. "Ophiuroidea," by H. Ludwig and O. Hamann, Bronn's Tierreich, Vol. 2, 1901. "The Ophiurans of the San Diego Region," by J. P. McClendon, U. of Cal. Pub., Vol. 6, 1909.

ber of small plates or scales, from which spines may project; a pair of these called the radial shields, which are at the base of each arm, are usually conspicuous. The plates surrounding the mouth form a complex system (Fig. 983), the largest ones being the five buccal plates in the interradii, one of which being also the madreporite. The five interradial projections, which determine the form of the star-shaped mouth, are called the jaws, and are composed each of a number of plates, from which the teeth, tooth papillae, and oral papillae project into the mouth. The arm contains typically four rows of superficial plates, an oral, an aboral, and two lateral rows, and these surround an axial row, which occupies almost the entire interior space of the arm; these plates are joined together by muscle and connective tissue strands. The paired ambulacral appendages pass between the ventral and the abutting lateral plates in each arm. The axial plates originate as paired structures, which unite more or less completely in the middle line. In a few forms the arms are without definite superficial calcareous plates. The lateral plates of the arms usually bear spines.

The mouth leads through a short œsophagus to the sac-like stomach which fills the disc. No liver sacs, rectum, or anus are present. The ambulacral canals are intra-skeletal and consist of ring and radial canals, the branch canals going to the ambulacral appendages, and the stone canal going to the madreporite. Each radial canal ends in a terminal tentacle; no ampullae are present. The ambulacral appendages are not locomotory, but tactile, respiratory, and excretory organs, and are called tentacles. The bursae take in and expel water, and probably aid in respiration and excretion. The entire nervous system is intra-skeletal.

The sexes are separate, with rare exceptions. The reproductive organs consist of a large number of gonads in the interradial areas of the disc, which open into the ten bursae. These pouches, which are invaginations of the body wall, receive the genital products and extrude them into the sea water; in *Amphiura squamata* and some other forms they retain them while development goes on, so that in these cases the young are born in the form of the adult. The gonads are all joined with the axial organ in a manner similar to that in starfish. The axial organ, which adjoins the stone canal, and is itself enclosed by the axial sinus, sends a strand to the aboral side of the body cavity, which there forms a ring. From this ring branches go to each group of gonads. The axial sinus accompanies the ring and its branches and finally surrounds each of the gonads. The larval brittle-star is called a pluteus. Brittle-stars have great regenerative powers; a lost arm is replaced, and in many cases the same is true of the upper surface of the disc, which may be

periodically shed; in a number of forms asexual reproduction by division of the disc occurs.

Distribution and Habits.—The *Ophiuroidea* form the most numerous class of echinoderms. They live on the sea bottom or among seaweed and coral colonies, feeding on small animals or organic matter of all sorts, and moving about by means of the long arms.

History.—The brittle-stars were included by the earlier zoologists among the starfishes, Linnæus having placed them in the genus *Asterias.* In 1816 Lamarck erected two new genera, *Ophiura* and *Euryale,* to include all the brittle-stars, but it was not until 1840 that Müller and Troschel published the first extended classification of them. In 1841 Forbes first made the group a separate class of the *Echinodermata.* The development of the pluteus larva was first described by J. Müller. The modern arrangement of the class is largely due to T. Lyman and F. J. Bell.

The class contains more than 1,100 species, which may be grouped in two orders.

Key to the orders of *Ophiuroidea:*

a_1 Arms unbranched and mostly with distinct and regular plates, and usually without the power of rolling in towards the mouth..1. OPHIURAE
a_2 Arms with superficial plates poorly defined or wanting, often branched, and with the power of rolling in towards the mouth.....2. EURYALAE

ORDER 1. OPHIURAE.

Brittle-stars with usually 5 unbranched arms which possess distinct articulating axial plates and cannot (except some of the *Ophiomyxidae*) be rolled towards the mouth: 7 families.

Key to the families of *Ophiurae* here described:

a_1 Arms with distinct and regular superficial plates.
  b_1 Lateral spines on the arms small and close to the surface.
    c_1 Disc granulated more or less closely.....1. OPHIODERMATIDAE
    c_2 Disc covered with scales or plates.....2. OPHIOLEPIDIAE
  b_2 Lateral spines stand out from the surface of the arm.
    c_1 Oral papillae present.
      d_1 No cluster of tooth papillae at apex of each jaw.
        e_1 Arm spines solid, often small and few.....3. AMPHIURIDAE
        e_2 Arm spines hollow, often long and numerous.....4. OPHIACANTHIDAE
      d_2 A cluster of tooth papillae at apex of each jaw.....5. OPHIOCOMIDAE
    c_2 No oral papillae present.....6. OPHIOTRICHIDAE
a_2 Arms and disc without regular and distinct superficial plates, soft and flexible.....7. OPHIOMYXIDAE

FAMILY 1. OPHIODERMATIDAE.

Oral papillae present, fringing the mouth; disc more or less closely covered with granules; plates of arm regular and distinct, the lateral plates bearing spines which lie close to the surface: 10 to 12 genera.

Ophioderma Müller and Troschel. Disc granular, with 4 bursal slits in each interradius; brachial spines short and smooth: 18 species; littoral, tropical, and mainly West Indian.

O. brevispina (Say) (*O. olivacea* Ayres) (Fig. 984). Disc pentagonal, 10 to 15 mm. in diameter; length of arm 40 to 60 mm.; color green or brownish: Cape Cod southwards, from the shore to 120 fathoms; common towards the south.

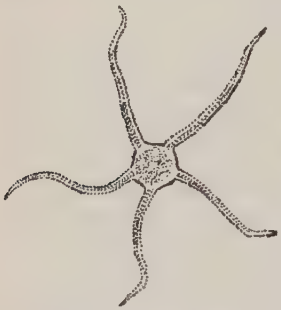

Fig. 984—*Ophioderma brevispina* (Clark).

Family 2. OPHIOLEPIDIDAE.

Oral papillae present; disc covered by scales or plates; arm plates regular, the lateral plates bearing small, closely lying spines: 25 genera.

Ophiura Lamarck. Disc with scales or plates; indentation of disc at the base of each arm usually fringed with minute spines called the arm comb; 2 bursal slits in each interradius: over 100 species; cosmopolitan.

O. sarsi Lütken. Disc with several large scales surrounded by small ones; arm comb made up of slender spinelets; 2 scales to each tentacle on middle of ray; diameter of disc 15 to 25 mm.; length of arm 50 to 100 mm.; color olive or brown: Casco Bay and northwards, in 10 fathoms and more; often very abundant; Europe; North Pacific.

O. robusta (Ayres). Diameter of disc 10 mm.; length of arm about 30 mm.; disc covered with small scales; 1 scale to each tentacle; color reddish: Cape Cod and northwards, from the shore to 150 fathoms; Europe.

Family 3. AMPHIURIDAE.

Oral papillae present, fringing the mouth; plates regular and distinct, the lateral arm plates bearing small, solid spines, which stand out from the surface of the arm: about 25 genera.

Fig. 985—*Ophiopholis aculeata* (Clark).

1. **Ophiopholis** Müller and Troschel. Arm spines rather stout and conspicuous; each upper arm plate surrounded by a series of small plates; aboral surface of disc covered with scales bearing granules or small spines: 5 species.

O. aculeata (L.). Daisy brittle-star (Fig. 983 and 985). Upper arm plates transversely oval; disc spines usually wanting in Atlantic coast specimens; color extremely variable; diameter of disc 2 cm.; length

of arm 7.5 to 12 cm.: Long Island Sound northwards, from low-water line to great depths; common towards the north; Europe.

2. **Amphipolis** Ljungman. Disc small, without spines but covered with scales; arms slender; outer oral papillae very wide, equal to both the inner ones: 20 species; cosmopolitan.

A. squamata (Delle Chiaje). Six oral papillae in each corner of mouth, the outer two very wide; 2 scales to each tentacle; color gray or yellowish; radial shields whitish; diameter of disc 2 to 4 mm.; length of arm 20 to 39 mm.; viviparous: Long Island Sound northwards, from low-water mark to 60 fathoms; Europe.

Family 4. OPHIACANTHIDAE.

Aboral surface of disc with granules or spinelets, which more or less conceal the scales; oral papillae present; plates of arm regular and distinct, the lateral plates bearing hollow spines which stand out from the surface: 20 genera.

Ophiacantha Müller and Troschel. Disc with small spines or granules; oral papillae long, 7 to 16 being in each corner of the mouth: about 100 species; cosmopolitan.

O. bidentata (Retzius). Diameter of disc 8 to 15 mm.; length of arm 40 to 50 mm.: Casco Bay and northwards, in 10 fathoms and more; Europe; Bering Sea.

Family 5. OPHIOTRICHIDAE.

Plates on upper side of the arms small; no oral papillae present, but a prominent group of tooth papillae at apex of each jaw; brachial spines stand out from the surface of the arm: 15 genera.

Ophiothrix Müller and Troschel. Surface of the disc covered with small spines and granules; radial plates large and triangular; 1 scale to each tentacle: 100 species.

O. angulata (Say). With a longitudinal stripe on upper side of arm; disc 8 to 12 mm. across; length of arms 5 cm.; color very variable, purplish or greenish: Chesapeake Bay and southwards.

Family 6. OPHIOMYXIDAE.

Arms and disc without distinct and regular plates and covered with a soft skin, so that the arms can be rolled in towards the mouth; oral papillae present: 8 genera.

Ophiomyxa Müller and Troschel. Disc and arms covered with a skin; arm spines short and but little imbedded in the skin: 12 to 15 species.

O. flaccida (Say). Diameter of disc 15 to 25 mm.; color olive or yellowish, sometimes very dark: Florida and West Indies.

Order 2. EURYALAE.*

Brittle-stars in which the arms are often branched and can be rolled in towards the mouth; axial plates of the arms double, the other plates rudimentary or wanting, and the surface of the body covered by a soft skin: 3 families.

Family ASTROPHYTIDAE.

Girdles of minute hooks on the arms, at least near the tips; teeth and the mouth and teeth papillae spiniform and indistinguishable from one another: about 20 genera.

Gorgonocephalus Leach. Disc circular or pentagonal, with radial shields on the aboral surface; each arm branches at its base, and from 11 to 15 times in addition: 8 species.

G. agassizi (Stimpson). Basket-fish (Fig. 986). Disc 4 to 8 cm. in diameter; length of arm 14 to 28 cm.: from Nantucket northwards, from extreme low-water mark to 800 fathoms; common towards the north.

Class 4. ECHINOIDEA.†

Sea-urchins. Echinoderms (Fig. 965), in which the five radii are not elongated so as to form arms but are approximately of the same length as the interradii, and the main body axis is short, so that the body is subglobular in form or disc-shaped. The calcareous plates are extensively developed and, except in the *Echinothuriidae,* fit closely together, forming a case, the "test" (Fig. 987), which encloses a spacious body cavity. The oral surface, with the mouth usually in its center, is more flattened than the aboral, and is directed downwards; on it the animal moves about. Surrounding the mouth is a circular, flexible area called the peristome (Fig. 966, B, 3), and projecting from the mouth in most sea-urchins are five calcareous teeth (Fig. 988). At the edge of the peristome are, in most species, five pairs of branched outgrowths called the gills (Fig. 966, B, 13). In the middle of the aboral surface is either the anus surrounded by a system of plates called the periproct (Fig. 987) or the madreporite (Fig. 990), the anus in the latter case being in an interradius at or near the edge of the test.

The ambulacral pores, through which the ambulacral appendages extend from body cavity to the outside, are, with rare exceptions, present only in the radii, four rows of pores appearing in each radius. In cer-

* See "Ueber Japanische und andere Euryalae," by L. Döderlein, Abh. 5, K. Bayer, Akad. Wiss., Math. Phys., Kl. 2, Supp.

† See "A Revision of the Echini," by A. Agassiz, Ill. Cat. Mus. Comp. Zool., No. 7, 1872-1874. "Hawaiian and Other Pacific Echini," by A. Agassiz and H. L. Clark, Mem. Mus. Comp. Zool., Vol. 34, 1907. "Comp. Morphology of the Echini," by R. T. Jackson, Mem. Bost. Soc. Nat. Hist. 1911. "The Genera of Recent Clypeastroids," by H. L. Clark, Ann. Am. Mag. Nat. Hist., Ser. 8, Vol. 7, 1911.

tain families the aboral ambulacral pores form a characteristic five-armed figure which somewhat resembles the petals of flower and is called the petaloid area (Fig. 990, 4). Inasmuch as the anus has shifted its position in these families to an interradius at the edge or on the oral side of the body, the latter can easily be divided by a longitudinal plane into a right and left half; in most spatangoids the mouth has also shifted its position towards the forward end, thus increasing the bilateral symmetry.

Sea-urchins are covered with spines which are movable and articulate with small tubercles by ball-and-socket joints. In some forms the

Fig. 986

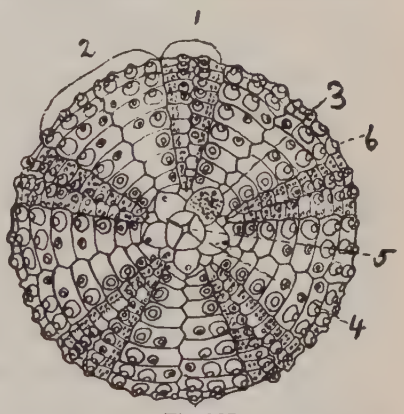

Fig. 987

Fig. 986—*Gorgonocephalus agassizi* (Clark). Fig. 987—Test of Arbacia—aboral aspect (Coe). 1, radius; 2, interradius; 3, madreporite; 4, genital plate; 5, anus; 6, spine tubercle.

spines are very long, and in some their tips are poisonous. A ciliated epithelium covers all parts of the body, except the large spines of certain forms. Stalked pedicellariae with usually three jaws occur between the spines and on the peristome, the movements of which are controlled by striated muscles. Sphæridia, minute, spherical bodies which are modified spines, occur in most cases on the oral surface; they are probably static organs.

Ambulacral appendages exist in three different forms: (1) locomotory feet with sucking discs, which are of very general occurrence; (2) ten large oral feet which surround the mouth on the peristome and may be organs of taste or smell; and (3) tactile or branchial appendages, without sucking discs, which characterize the petaloid area.

Internal Structure.—The calcareous plates in the body wall, which form the test, fall into three groups, the peristomal, the coronal, and the apical. The corona forms the greater part of the test. It is composed of twenty rows of polygonal plates (Fig. 987), which, in most sea-

urchins, fit immovably together and extend from the peristome on the oral side to the apical plates on the aboral side of the body. Two of these rows are situated in each radius (1) and two in each interradius (2), the radial plates, as we have just seen, being pierced by the ambulacral pores. The plates of the corona bear the tubercles (6) on which the spines articulate.

The peristome is sometimes without plates and entirely membranous; in some forms small irregular plates are imbedded in it; in some it contains rows of plates which are continuous with those of the corona. The apical plates occupy the center of the aboral surface. In the regular sea-urchins (Fig. 987) they consist of the anal plates which surround the anus (5) and form the periproct, the five genital plates (4) at the aboral ends of the five interradii, in each of which is a genital pore, and five radial plates at the aboral ends of the five radii. Each of the latter is pierced by a pore through which the terminal end of the radial canal projects; inasmuch as it is pigmented, it was formerly supposed to be an eye, and the plate is generally called the ocular plate. In the regular sea-urchins one of the genital plates is the madreporite (3). In the other sea-urchins the anal plates are not in the apical system and the arrangement of the other plates is changed, the madreporite being usually in the center of the group (Fig. 990, 3).

The ambulacral system consists of a ring canal (Fig. 966, B, 4) around the œsophagus and five radial canals (7) which pass along the radii on the inner surface of the shell to the radial plates, through which they project. The branches going to the feet possess each an ampulla. The stone canal (5) passes from the ring canal to the madreporite and is surrounded by the axial sinus with its axial organ.

The alimentary canal consists of a wide tube (6) which, beginning at the mouth, winds completely around the inner wall of the body cavity, then, turning on itself, winds around again in the opposite direction and ends at the anus. An accessory gut branches off from the intestine near the mouth and, running along parallel with it, joins it near its middle. In most sea-urchins a complicated dentary apparatus (12), sometimes called the lantern of Aristotle, surrounds the œsophagus. It is composed of five groups of calcareous plates bound together by muscles, and from it five calcareous teeth project through the mouth to the outside.

Respiration and excretion are performed by the entire surface of the body, and especially by the ambulacral appendages, the peristomal gills, and perhaps the accessory intestine. The superficial oral nervous system is intra-skeletal, lying along the ambulacral vessels. Special sense organs are poorly developed. Sphæridia are almost universally present. In some genera pigment eyes are distributed over the body.

The sexes are separate. The gonads are usually five in number and lie in the upper part of the body cavity, opening to the outside through the genital pores. Each is joined by a cord with an apical ring which, as in the starfish, is connected with the axial organ. The genital products are thrown into the sea water; the larva is similar in form to that of the *Ophiuroidea,* and is also called a pluteus.

Distribution and Habits.—Sea-urchins occur in all seas, being most numerous in the neighborhood of the coast, although many deep-sea forms occur. They move slowly about by means of the ambulacral feet and the spines, and live on small forms of life and organic remains of all kinds; many species pass large quantities of sand and mud through the intestine. Some sea-urchins hollow out excavations in rocks, in which they live. Certain species, in France and Italy and other countries, are used for food, the genital organs being eaten; over 100,000 dozen sea-urchins are yearly brought into the fish markets of Marseilles.

History.—Aristotle was acquainted with several species of sea-urchins and the name *Echinus* originated with him. He was also acquainted with certain features of their anatomy, and mentions the similarity in appearance of the dentary apparatus to a lantern. The first attempt in more recent times to classify them was made by Klein (1734). The knowledge of sea-urchins did not, however, increase rapidly until the following century. In 1816 appeared Tiedmann's important works on their anatomy, and in the fourth and fifth decades of the century the foundations of the modern classification were laid by Desor and Louis Agassiz, while the metamorphosis was studied by J. Müller. In modern times A. Agassiz, H. L. Clark and R. T. Jackson have done the most to extend the knowledge of the group, especially of the American forms.

Modern *Echinoidea* contain 4 orders, with about 500 species. More than 2,000 fossil species are known.

Key to the orders of *Echinoidea:*

a_1 Without peristomal gills; peristome with plates; mouth central; anus apical ..... 1. CIDAROIDA

a_2 With peristomal gills.

b_1 Dentary apparatus present; mouth central.

c_1 Anus apical ..... 2. CENTRECHINOIDA

c_2 Anus in posterior interradius; test depressed or discoidal. 3. CLYPEASTROIDA

b_2 Dentary apparatus wanting; anus not apical ..... 4. SPATANGOIDA

ORDER 1. CIDAROIDA.

Sea-urchins which have no peristomal gills; ambulacral areas narrow and inter-ambulacral areas broad, and both continued on the peristome to the mouth; spines large and long: 1 family, with about 60 species, mostly in the warmer seas.

Family CIDARIDAE.

With the characters of the order: 10 to 12 genera.

Eucidaris Pomel. Oral and aboral surfaces flattened; test thick; interambulacral areas 3 times as broad as the ambulacral; primary spines usually shorter than the diameter of the test, stout, fluted, and granulated; between these are smaller spines: 3 species.

E. tribuloides (Lamarck). Diameter 4 to 7 cm.; color of primary spines grayish, broad and flat: South Carolina to Brazil; common; from shore to 116 fathoms.

Order 2. CENTRECHINOIDA.

Sea-urchins with peristomal gills and sphæridia; mouth central, with jaws; anus apical: 10 or 11 families.

Key to the families of *Centrechinoida* here described:

a_1 Test more or less flexible.....1. Echinothuriidae
a_2 Test rigid.
b_1 Large spines hollow.....2. Centrechinidae
b_2 Spines solid.
c_1 Periproct with but few, usually 4, plates.....3. Arbaciidae
c_2 Periproct with many plates.
d_1 Ambulacral plates with 3 pairs of pores.....4. Echinidae
d_2 More than 3 pairs of pores.....5. Strongylocentrotidae

Family 1. ECHINOTHURIIDAE.

Test flexible, the plates being movable and overlapping one another; peristome with ambulacral plates and feet, but without interambulacral plates: 6 genera.

Phormosoma Wyville Thompson. Difference between oral and aboral sides marked; primary spines on the oral side encased in a thick membrane: 4 species.

P. sigsbei (A. Agassiz). Diameter 6 to 8 cm.; spines small, reddish-orange in color: West Indies, in deep water.

Family 2. CENTRECHINIDAE.

Sea-urchins with peristomal gills; ambulacral areas narrow; interambulacral areas large; spines long and hollow; the tubercles to which they are attached with a central perforation; aboral ambulacral feet without suckers: 9 genera; mostly in the Pacific and Indian Oceans; 20 to 25 species.

Centrechinus Jackson (*Diadema* Gray). Test circular in outline, somewhat flattened, about twice as wide as high; colors very dark; blue eye spots often present on the genital plates and elsewhere: 6 species.

C. antillarum (Philippi) (*Diadema setosum* Gray). Spines black, very slender and long, and poisonous; diameter 8 to 10 cm.: Florida and West Indies; very common in shallow water among rocks and corals.

Family 3. ARBACIIDAE.

Sea-urchins with a circular outline and with peristomal gills; spines solid and rather large; ambulacral areas narrow; aboral ambulacral feet without suckers: 7 genera and 18 species.

Arbacia Gray. Subglobular or pyramidal sea-urchins; interrays naked at the aboral end: 5 or 6 species.

A. punctulata (Lamarck) (Fig. 988). Color reddish-brown; diameter 3 to 5 cm.; height 15 to 25 mm.; length of spines 20 to 25 mm.: Cape Cod, southwards to Yucatan, from low-water mark to 120 fathoms; common.

Fig. 988—*Arbacia punctulata*—oral aspect (Coe).

Family 4. ECHINIDAE.

Sea-urchins with a circular outline, with peristomal gills and a single pair of ambulacral plates at the base of each ray in the peristome; each ambulacral plate with 3 pairs of pores; periproct composed of numerous plates: 9 genera and more than 50 species.

1. Lytechinus A. Agassiz (*Toxopneustes* Agassiz). Spines short; tubercles all of about the same size and in several rows; peristome large: 8 species.

L. variegatus (Lamarck). Diameter 5 to 8 cm.; height 3 to 4.5 cm.; color green, often with more or less purple; spines rather short and slender: North Carolina to Brazil, from low-water mark to 30 fathoms.

2. Tripneustes Agassiz (*Hipponoë* Gray). Large sea-urchins with a thin shell and numerous small tubercles on which are small spines: 3 species.

T. esculentus (Leske). Test 10 to 15 cm. in diameter, semi-globular; color white: South Atlantic coast and West Indies; used for food by the West Indian negroes.

Family 5. STRONGYLOCENTROTIDAE.

Sea-urchins with a circular outline; 4 to 11 pairs of pores in each ambulacral plate: 8 genera and about 30 species.

Strongylocentrotus Brandt. Spines slender and fluted; tubercles not all of the same size, arranged in numerous series and often crowded: about a dozen species.

S. dröbachiensis (O. F. Müller). Green urchin. Diameter 4 to 8 cm.; length of spines 8 to 15 mm.; color green: New Jersey northwards, very common north of Cape Cod; from shore to 650 fathoms; Europe; Asia; Pacific coast.

Order 3. CLYPEASTROIDA.

Sea-urchins in which bilateral symmetry of outer form has been secondarily acquired; anus in posterior interradius at margin of test or on oral surface; test more or less depressed or discoidal; mouth central, with a dentary apparatus: 6 families.

Family 1. CLYPEASTRIDAE.

Bilaterally symmetrical sea-urchins with a thick shell covered with short spines; in the center of the aboral surface is the madreporite, from which radiate the five petaloid ambulacral areas: 2 genera and 20 species.

Fig. 989 *Clypeaster subdepressus* (Leunis).

Clypeaster Lamarck. Shell more or less five-sided, each petaloid area being wide and well marked; each pair of ambulacral pores in the petals joined by a groove; 5 genital pores: about 20 species.

C. subdepressus Gray (Fig. 989). Shell thick and quite flat; color in life yellowish-green or purplish; length 12 cm.; width 8 cm.: from the shore to 40 fathoms; North Carolina to Brazil.

Family 2. SCUTELLIDAE.

Shell very flat, more or less circular, and covered with minute spines; in the center of the aboral surface is the madreporite, from which radiate the five well-marked petaloid areas: 8 genera and about 20 species.

1. **Echinarachnius** Leske. Shell a circular disc; each petal wide and with open ends; 4 genital pores: 5 species.

E. parma (Lamarck). Sand dollar (Fig. 990). Diameter 7 cm. or less, the shell being slightly broader than long: Long Island Sound northwards, from low-water mark to 800 fathoms; Pacific coast; common.

2. **Mellita** Agassiz. Test a circular disc pierced by 5 or 6 elongated holes; each petal with closed ends; ambulacral grooves on the oral side much branched; anus between the mouth and the interradial hole in the shell: 4 species.

M. quinquiesperforata (Leske). Keyhole urchin (Fig. 991). Five holes present, 1 interradial and 1 distal to each lateral petal; diameter of test 8 to 12 cm.: Vineyard Sound southwards, in shallow water; rare north of Cape Hatteras.

3. **Encope** Agassiz. Test heavy, flat underneath, somewhat arched above, elliptical, truncated behind and with 5 marginal notches or elongated holes; hinder interradial area also with an elongated hole: 6 species, littoral; tropical America.

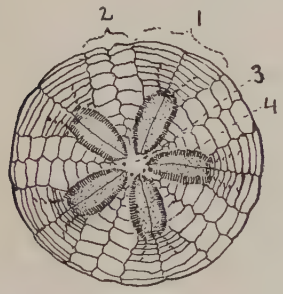

Fig. 990

Fig. 991

Fig. 990—*Echinarachnius parma,* spines removed (Coe). 1, radius; 2, interradius; 3, madreporite; 4, petaloid. Fig. 991—*Mellita quinquiesperforata* (Clark.)

E. michelini Ag. Margin of test indented opposite the end of the petals (at least the lateral ones), these indentations rarely if ever closed at distal ends so as to form holes; length and width 14 cm. or less: Florida and Gulf coast.

Order 4. SPATANGOIDA.

Body secondarily bilaterally symmetrical; mouth near the forward end of the body and without a dentary apparatus; anus at or near the hinder margin of the body; aboral ambulacral areas petaloid, the forward, median area usually differing somewhat from the other four, which are paired, in appearance: about 36 genera and more than 150 species grouped in 9 families; tropical and subtropical.

Family SPATANGIDAE.

Body more or less heart-shaped; petals well marked: numerous genera and species.

Moira Michelin. Body ovate; apical area behind the middle; ambulacral grooves deep and slit-like; mouth far in advance of the middle: 3 species.

M. atropos (Lamarck). Length 5 cm.: North Carolina, southwards; common in shallow water.

Class 5. HOLOTHURIOIDEA.*

Sea cucumbers. Holothurians. Echinoderms in which the main body axis is very long (Fig. 965, D) so that the form is often quite worm-like. The oral surface is not directed towards the ground, as in most echinoderms, but the animal rests on the side of the cylindrical body, with the body axis parallel with the ground, the oral surface forming the anterior and the aboral surface with the anus the posterior end. This arrangement may be sometimes disturbed, however, and in *Rhopalodina lageniformis* of the west African coast the mouth and anus are side by side on the upper surface. The side on which the holothurian rests and which is thus its ventral side is often flattened and consists of three radii and two interradii, the remaining two radii and three interradii forming the dorsal surface.

The calcareous plates are mostly minute and the body wall thus lacks the rigidity of other echinoderms. The external surface is not ciliated and is without spines or pedicellariae. The ambulacral appendages exist in a variety of forms: around the mouth are ten or more long, branched, oral tentacles; ambulacral feet may occur on all sides of the body, or only on the ventral side of it, and ambulacral tentacles without suckers (papillae) may occur on the dorsal side. The oral tentacles are alone present in several groups. The ambulacral feet and papillae may occur in rows in the radii or may be scattered irregularly over both radii and interradii.

Internal Structure.—The alimentary canal is a long tube which runs from the mouth at the forward end of the body to the anus at the hinder end, generally turning on itself twice. The hinder portion is enlarged and from it in several families long tubular sacs extend into the body cavity. These are of two kinds, which are called the respiratory tree and Cuvier's organs, respectively. The former are a pair of extensively branched organs in and out of which water is pumped through the anus; they are consequently respiratory in function. The latter are unbranched, glandular tubes connected with the terminal portion of the respiratory tree and are found only in certain species. They are exceedingly extensile and sticky and can be thrust out through the anus and be used to entangle an enemy, having thus a defensive function. The body wall is well provided with muscles, powerful longitudinal muscles running along the radii and transverse muscles being in the interradii.

The ambulacral system consists of a ring canal, well within the body cavity around the œsophagus with one or more Polian vesicles, five radial

* "Holothurians of the Challenger," by H. Théel, 1886. "Holothurians," in Bronn's Tierreich, by H. Ludwig, 1889-92. "Holothurioidea," by H. L. Clark, 1901, Amer. Nat., Vol. 35, pp. 479-496. "The Apodous Holothurians," by H. L. Clark, 1908.

canals which pass along the inner surface of the radii between or external to the longitudinal muscles, the ambulacral appendages, and the stone canal. The ambulacral feet are provided with ampullae. Tentacular canals branch off from the radial canals and pass to the tentacles, which may also have ampullae. The stone canal in most holothurians does not extend to the body wall but ends free in the body cavity, receiving through the madreporite the body fluid. In some deep-sea forms and rarely in synaptids it reaches the body wall; in many holothurians more than one canal is present. The superficial nervous system consists of a nerve ring around the mouth and radial nerves which proceed along the radial ambulacral canals. Special sense organs are better developed than any other class of echinoderms and pigment eyes, otocysts, olfactory cups, and taste papillae are all known. The tentacles also are important tactile organs. The respiratory and excretory functions are performed by the respiratory trees and the ambulacral appendages.

The reproductive organs consist of a single, branched gonad which opens to the outside on the dorsal surface either within the ring of oral tentacles or back of it; this gonad is probably homologous to the axial organ of other echinoderms. The sexes are usually separate, but certain hermaphrodites occur. The larval form is called the auricularia. In a number of species the young are hatched in the body cavity, where they undergo development, ultimately emerging through a rupture of the body wall. Several species carry the eggs and young in brood pouches. Like all echinoderms, holothurians have great regenerative powers; individuals which have voided the viscera may live and regenerate the lost parts, and some species have been observed to break themselves in two by transverse division, each half developing into a complete animal.

Distribution and Habits.—Holothurians occur in most seas. They are found at all depths, some species moving over the bottom swallowing sand or mud and catching minute organisms, some living among rocks, corals, or seaweeds, while others bury themselves in the sand or mud. They are used for food extensively in the Far East, the trepang of the Chinese being the dried bodies of *Holothuria marmorata* and other species.

History.—The name *Holothuria* originated with Aristotle although much doubt exists as to what animals he applied it. Rondelet, however, and other medieval authors gave it to undoubted holothurians. The first anatomical discriptions of holothurians were given by Bohadsch (1761) and Pallas (1766). Linnæus in 1758 gave the name to the Portuguese man-of-war (*Physalia*), and by a strict interpretation of the law of priority it should still be given to this genus. O. F. Müller, however,

in 1776 described a considerable number of species, all of which he included in the genus *Holothuria,* as did other authors of his time. Cuvier in 1817 also placed all the known species in this genus, which he first put in the class *Echinodermata,* the relationship of holothurians to starfish and sea-urchins not having been generally recognized before his time. Goldfuss (1820), following Oken, divided the group into several genera, but Jäger (1833) again united all in the single genus *Holothuria.* He, however, subdivided it into three subgenera and these into tribes, and his whole arrangement may be considered the foundation of the modern classification. Of great importance in more recent times have been Semper's work on the holothurians of the Philippines (1867) and the anatomical and systematic studies of Selenka and Ludwig.

The class contains two orders and six or eight families, with over 500 species.

Key to the orders of *Holothurioidea:*

a_1 Ambulacral feet present, or if wanting, respiratory tree present. 1. ACTINOPODA

a_2 Ambulacral feet and respiratory tree both absent.....2. PARACTINOPODA

ORDER 1. ACTINOPODA.

This order includes the majority of sea cucumbers and all those in which the oral tentacles spring from the radial canals alone; ambulacral feet are present except in the *Molpadiidae:* 7 families.

Key to the families of *Actinopoda* here described:

a_1 Ambulacral feet present.
b_1 Oral tentacles branched only at tip.....1. HOLOTHURIIDAE
b_2 Oral tentacles much branched.....2. CUCUMERIIDAE
a_2 Ambulacral feet absent.....3. MOLPADIIDAE

FAMILY 1. HOLOTHURIIDAE.

Holothurians usually elongated and more or less cylindrical in shape, which have 18 to 30 (usually 20) oral tentacles, the branches of each of which form a frilled and expanded end; tentacular ampullae present; genital pore outside the ring of tentacles; respiratory tree well developed: 6 to 8 genera and about 200 species, which are found principally in the tropics, especially in the Indian and Pacific Oceans; about 13 species are used by the Chinese for food, and enter into the commerce of the East under the name of trepang.

HOLOTHURIA L. Twenty oral tentacles (occasionally more); ambulacral appendages scattered over the entire body; calcareous bodies in body wall numerous and very diverse in form: over 100 species, at least 4 of which occur on the Florida coast.

H. floridana* Pourtalès (*H. mexicana Ludwig*). Body elongated, cylindrical, 20 to 40 cm. long; color brown or yellowish, often reddish below; ambulacral appendages with suckers on the under surface and with or without them on the upper: Florida and West Indies.

Family 2. CUCUMERIIDAE.

Holothurians with 10 to 20 branched oral tentacles; ambulacral feet and respiratory tree present; genital pore often inside the ring of tentacles: 12 genera and over 200 species.

Key to the genera of *Cucumeriidae* here described:

a_1 Lower surface of body not flattened, the distribution of its ambulacral appendages not different from that of the upper surface.
b_1 Feet in rows and mostly confined to the radii.....1. Cucumaria
b_2 Feet scattered thickly over the entire surface.....2. Thyone
a_2 Lower surface flattened to form a distinct creeping sole; 10 tentacles; no feet on the upper surface.....3. Psolus

1. Cucumaria Blainville. Body usually thick, with 10 tentacles and with feet in rows in the radii, a few feet often being also scattered over the interradii, at least dorsally: 73 species.

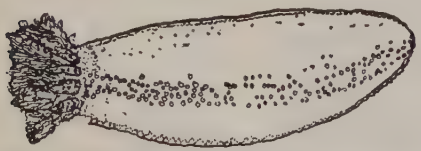

Fig. 992

Fig. 992—*Cucumaria frondosa* (Clark).

Fig. 993

Fig. 993—*Thyone briareus* (Clark).

C. frondosa (Gunnerus) (Fig. 992). Length 20 to 30 cm.; thickness 10 cm.; color reddish or brown, much darker above than below; a few ambulacral appendages on the interradii: Nantucket and northwards from low-water mark to 200 fathoms; abundant on the Maine coast; Europe.

C. pulcherrima (Ayers). Length 5 cm.; thickness 2 cm.; body ovate; color whitish; no feet on the interradii: Vineyard Sound to South Carolina, in shallow water.

2. Thyone Oken. Body ovate or elongate, with 10 tentacles and with feet scattered thickly over the entire surface: 39 species.

T. rubra Clark. Red above, whitish below; 20 mm. long; viviparous: California.

T. briareus (Lesueur) (Fig. 993). Length 12 cm.; thickness 3 cm.; color dull brown, or black: Vineyard Sound and southwards, in mud in shallow water; locally common.

* See "The Development of Holothuria floridana," by C. L. Edwards, Jour. Morph., Vol. 20, p. 211, 1909.

3. **Psolus** Oken. Lower surface of body forms a creeping sole on which are the feet in rows; 10 oral tentacles; upper surface arched, without feet, and usually with large calcareous scales: 13 species.

P. phantapus (Strussenfeldt). Body thick, with 3 rows of feet; anal region caudiform; color brownish, reddish, or yellowish; length 15 cm.: Cape Cod and northwards, from low water to 150 fathoms; Europe.

P. fabricii (Düben and Koren). Body wide, with 2 rows of feet, one row on each edge of the creeping sole; color of upper side bright red, the under side lighter; length 10 to 13 cm.: Cape Cod and northwards, in shallow water; Alaska; Europe; Asia.

Family 3. MOLPADIIDAE.

Body elongated, cylindrical and without ambulacral feet; 15 tentacles usually present, which are either cylindrical or have minute branches; tentacular canals spring from the radial canals and usually have ampullae: 8 genera and about 50 species.

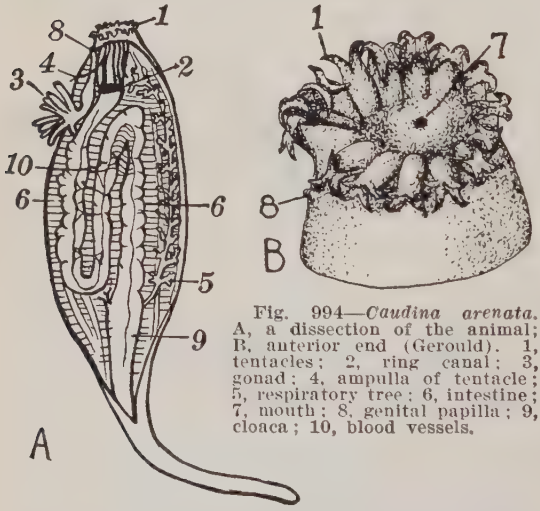

Fig. 994—*Caudina arenata.* A, a dissection of the animal; B, anterior end (Gerould). 1, tentacles; 2, ring canal; 3, gonad; 4, ampulla of tentacle; 5, respiratory tree; 6, intestine; 7, mouth; 8, genital papilla; 9, cloaca; 10, blood vessels.

Caudina Stimpson. Body tapers posteriorly into a more or less evident tail: 8 species.

C. arenata (Gould) (Fig. 994). Tentacles short, each with 4 branches at the tip; color pink or purplish; length 10 to 17 cm., about a third of which is "tail": Newport, Rhode Island, to the Gulf of St. Lawrence, from low water to 18 fathoms; locally common.

Order 2. PARACTINOPODA.

Holothurians without ambulacral feet, with 10 to 25 feathered, digitate or simple tentacles, whose tentacular canals spring from the ring canal, and with 1 to 50 Polian vessels; ampullae, radial canals, respiratory tree, and Cuvier's organs wanting; mostly hermaphroditic: 1 family.

FAMILY SYNAPTIDAE.

Characters as given above: 21 genera and nearly 100 species.

Key to the genera of *Synaptidae* here described:

a_1 Calcareous bodies are anchors and plates.....1. LEPTOSYNAPTA
a_2 Calcareous bodies are wheels.....2. CHIRIDOTA

1. LEPTOSYNAPTA Verrill. Body long, worm-like, and semi-transparent; 10 to 13 pinnate tentacles present; 1 stone canal and Polian vessel; calcareous bodies in form of anchors with serrate arms accompanied by perforated plates: 9 species.

L. inhærens (O. F. Müller) (Fig. 995). Tentacles 12, each of which has 5 to 7 pairs of side branches; color whitish; length 10 to 30 cm.; thickness 5 to 10 mm.: Maine to South Carolina; common in the sand from the shore to 100 fathoms; Pacific coast; Europe.

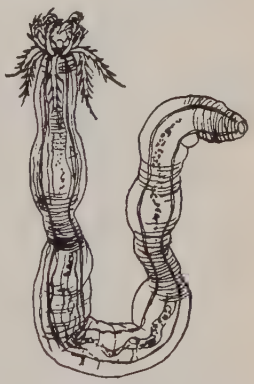

Fig. 995
Leptosynapta inhærens (from Bronn).

L. roseola Verr. Tentacles 12, each of which has 2 or 3 pairs of side branches; color rosy red; length 10 cm. or less: Cape Cod to Long Island Sound, under stones and occasionally in the sand, near low-water mark, not so common as the preceding; Bermuda.

2. CHIRIDOTA Eschscholtz. Tentacles 12, each with a short stalk which widens distally and bears 3 to 10 pairs of side branches; calcareous bodies in form of wheels usually with 6 spokes: 12 to 15 species.

C. lævis (Fabricius). Papillae containing the wheels in rows of 20 to 30 in each dorsal interambulacral area and 3 to 12 in each ventral area; color pink to translucent white; length 10 to 15 cm.: Cape Cod and northwards, from low-water mark to 45 fathoms, also in deeper water; locally abundant; Europe; Pacific.

PHYLUM VIII.

CHORDATA.

Animals possessing the following structural features: (1) a notochord, a cylindrical rod lying along the mid-dorsal line of the digestive tube, from the dorsal wall of which it has arisen, and ventral to the central nervous system; (2) a pharyngeal respiratory apparatus consisting of paired gill slits in the wall of the pharynx, which place that structure in communication with the exterior; and (3) a tubular, dorsal central nervous system. In the air-breathing chordates, the notochord and the gill slits are present only in the embryo, and in the adult are replaced by the spinal column and the lungs.

The phylum contains about 37,000 species, of which over 35,000 are vertebrates, grouped in 4 subphyla.

History.—This phylum was formed in 1874 by Haeckel as a result of the epoch-making studies of Kowalevsky of *Balanoglossus*, ascidians, and *Amphioxus* in the preceding decade.

Key to the subphyla of *Chordata:*

a_1 Body (in the American species) long and worm-like.
a_2 Body not worm-like. ..... 1. ENTEROPNEUSTA (*Hemichordata*)
b_1 Body more or less sac-shaped ..... 2. TUNICATA (*Urochordata*)
b_2 Body lanceolate ..... 3. LEPTOCARDIA (*Cephalochordata*)
b_3 Vertebrates (not included in this book) ..... 4. VERTEBRATA

SUBPHYLUM 1. ENTEROPNEUSTA.* (HEMICHORDATA.)

Chordata in which the notochord consists of a hollow, dorsal projection of the anterior portion of the digestive tract (Fig. 996, 13). The body is unsegmented and soft in texture, and is composed of three portions, the preoral lobe or proboscis (1), the collar (2), and the trunk (3). The subphylum is composed of two orders, the *Balanoglossida* and the *Cephalodiscida*, the latter order containing a very few species of marine and largely deep-sea animals which are not found near our coasts.

* See "Les Procordés," by Delage et Hérouard, Traité de Zool. Coner, Vol. 8, 1898. "The Development of Balanoglossus," by W. Bateson, Quart. Jour. Mic. Sci., Vols. 24-26, 1884-1886. "Growth and Development of Balanoglossus," by T. H. Morgan, Jour. Morph., Vol. 5, p. 407, 1891. "Die Enteropneusten des Golfes von Neapel," etc., by J. W. Spengel, Fauna and Flora, etc., 1893. "Die Benennung d. Enteropneustengattungen," by same, Zool. Jahrb., System. Ab., Vol. 16, p. 219, 1901. "Hemichordata," Camb. Nat. Hist., 1904.

History.—This group was first formed by Gegenbaur in 1870, who placed it among the worms. When, however, the fundamental researches of Kowalevsky became known and their significance appreciated the relationship of the group to the *Tunicata* and *Amphioxus* was universally recognized, and in 1884 it was brought under the *Chordata* by Bateson, who at the same time proposed the name *Hemichorda* for it.

Order BALANOGLOSSIDA.

Elongated, worm-like *Enteropneusta,* which are often common on sand flats. The proboscis is a cylindrical or ovoid structure joined with the collar by a narrow neck. It contains a portion of the cœlom which opens to the outside by a dorsal pore (5), or in some cases by two; the collar also contains two similar cavities, each with its pore. The trunk has an extensive cœlom in the form of a pair of elongated cavities between which lies the digestive tract (9), supported by a dorsal and a ventral longitudinal mesentery. This tract is straight and extends from the mouth at the anterior end of the collar to the anus at the hinder end of the body: from its anterior end a dorsal finger-shaped diverticulum (13), which represents the notochord, extends forwards into the proboscis. The entire anterior portion of the intestinal tract is placed in direct communication with the exterior by a series of paired gill slits (10), back of which in certain genera is a series of paired liver sacs which show conspicuously on the outer surface of the body. A dorsal (7) and a ventral (11) blood vessel accompanies the intestine, the former of which passes above the notochord and ends in a sinus (4) situated in the collar and proboscis. The nervous system is mostly sub-epithelial and diffuse. Mid-dorsally in the collar and mid-ventrally in the trunk, however, are definite aggregations of nerve cells and fibers which are joined by a ring nerve just behind the collar. The portion of the dorsal strand (6) in the collar is tubular in shape and distinct from the outer epithelium and arises as a neural canal, like the central nervous system of vertebrates: in certain genera it is still joined with the outer epithelium by a series of median nerves called nerve roots.

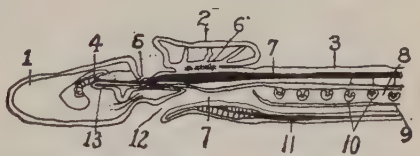

Fig. 996—Diagram of a longitudinal section of Balanoglossus (Shipley and MacBride). 1, proboscis; 2, collar; 3, trunk; 4, heart; 5, proboscis pore; 6, nervous system; 7, dorsal blood vessel; 8, branchial region of intestinal tract; 9, pharyngeal region; 10, gill slits; 11, ventral blood vessel; 12, mouth; 13, notochord.

The sexes are separate, the gonads appearing as paired pouches along the branchial region and back of it, each pouch opening to the outside

by a separate pore. The sexes often differ from each other in color. The development is a metamorphosis, the characteristic larva, which is called the tornaria, resembling the larvae of the echinoderms in form and structure. This larva is not present, however, in *Balanoglossus aurantiacus,* one of the most familiar American forms.

The American *Balanoglossida* live mostly in shallow water, in the sand and mud, in which they burrow with aid of the proboscis. The animals leave a coiled mass of sand held together by mucous on the surface of the sand, which indicates the presence of the burrow; they also give out a disagreeable odor. They were first described by Eschscholtz in 1825, who put them in the genus *Ptychodera,* while Delle Chiaje in 1829 gave them the generic name *Balanoglossus,* which has been the familiar name of the animals ever since. About 25 species are known, which are grouped in 4 families.

Key to the American families of *Balanoglossida:*

a_1 Liver sacs present.....1. PTYCHODERIDAE
a_2 Liver sacs absent.....2. HARRIMANIIDAE

FAMILY 1. PTYCHODERIDAE.

Paired liver sacs present behind the gill slits; chitinous rods supporting the gill arches joined by connecting bars (synapticula); central nervous system with nerve roots: 3 genera.

1. PTYCHODERA Eschscholtz. Gill openings to outside are long slits; a pair of longitudinal dorsal wing-like lobes (genital wings) present in the genital region: 10 species.

P. biminiensis Willey. Body large and finger-thick; proboscis short: Bahamas.

2. BALANOGLOSSUS Delle Chiaje. Gill openings to outside are small pores; proboscis short, with paired pores; medial gonads present: 5 species.

B. aurantiacus (Girard) (*B. brooksii* Bateson). Length 15 cm. or more, sometimes a meter; color bright purplish or greenish: North and South Carolina.

B. jamaicensis Willey. Body large, with transverse red bands: Jamaica.

FAMILY 2. HARRIMANIIDAE.

Liver sacs, synapticula, and nerve roots absent: 2 genera.

1. **DOLICHOGLOSSUS** Spengel. Proboscis long and with but one pore; medial gonads absent: 5 species.

D. kowalevskyi* (A. Agassiz) (Fig. 997). Length 15 cm. or more; color of proboscis pinkish-yellow; collar same color but darker; body orange yellow: Massachusetts Bay to Beaufort, N. C.; often common on clean sand flats.

D. pusillus Ritter. Length 20 cm. or more; color orange: southern California.

2. **Harrimania** Ritter. Proboscis short, with 2 pores: 1 species.

H. maculosa Rit. Length 10 cm.; proboscis 13 mm., collar 4 mm., abdomen 89 mm. long; color dark grayish-green; proboscis mottled: southern California; often common.

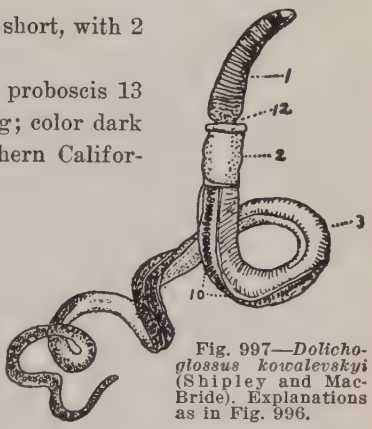

Fig. 997—*Dolichoglossus kowalevskyi* (Shipley and MacBride). Explanations as in Fig. 996.

Subphylum 2. TUNICATA.† (Urochordata.)

Degenerate *Chordata* in most of which the body of the adult is more or less cylindrical or globular in shape and is encased in a characteristic cuticular covering called the tunic (Fig. 998, 7). This tunic is secreted by the underlying epidermal cells, but in most tunicates differs from a typical cuticula in that it is composed largely of cellulose and contains also mesenchyme cells, which have migrated into it, and also blood spaces. Immediately beneath the tunic is a second very definite structure called the mantle (11), which is a firm, composite tissue made up of connective tissue fibers and enclosing muscles and blood vessels. Very characteristic are the large pharynx, or branchial sac, and the endostyle. The former (8) is the anterior portion of the digestive tract and occupies the greater portion of the body. The mouth leads into it, and through the openings in its walls the respiratory water streams either directly to the outside, as in the *Larvacea,* or, as in the other tunicates, into the large cloacal or peribranchial space (Fig. 999, 10), which communicates with the outside through the cloacal aperture. The endostyle (6) is a glandular, ciliated groove which lies in the mid-ventral

* See "The History of Balanoglossus and Tornaria," by A. Agassiz, Mem. Amer. Acad. Arts and Sci., Vol. 9, p. 421, 1873.

† See "Description of Some Imperfectly Known and New Ascadians from New England," by A. E. Verrill, Am. Jour. Sci. and Arts, 3rd ser., Vol. 1, 1871. "The Invert. of Vineyard Sound," Rep. of U. S. Fish. Com., 1873. "A Revised Class. of Tunicata," by W. A. Herdman, Jour. Linn. Soc. Zool., Vol. 23, p. 558, 1891. "Tunicata," by O. Seeliger and R. Hartmayer, Bronn's Klass. u. Ord. des Thierr., 1895-1911. "The Pelagic Tunicata of the San Diego Region, excepting the Larvacea," by W. E. Ritter, U. of Cal. Pub. Zool., Vol. 2, p. 51, 1905. "The Pelagic Tunicata," by W. E. Ritter and E. S. Byxbee, Mem. Mus. Comp. Zool., Vol. 26, 1905.

line of the pharynx, the secretions of which serve to entangle the minute organisms which form the food of the animals, and the action of whose cilia carries these forward to the ciliated peripharyngeal band (Fig. 998, 5) which surrounds the anterior end of the pharynx. This band passes the food dorsally to the dorsal lamina (9), a ciliated band in the mid-dorsal line, along which it is carried to the opening of the œsophagus at the inner end of the pharynx. The short œsophagus joins the pharynx with the stomach (15), from which the intestine passes to the anal opening into the cloacal space.

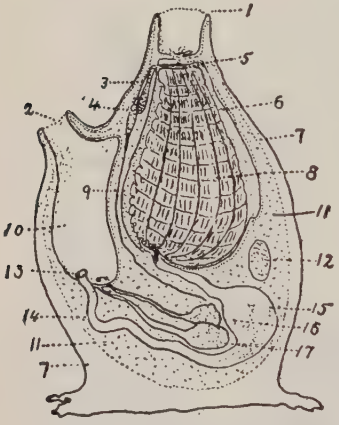

Fig. 998—Diagram of a simple ascidian (Boas). 1, mouth; 2, cloacal opening; 3, subneural gland; 4, principal ganglion; 5, peribranchial ridge; 6, endostyle; 7, tunic; 8, pharynx; 9, dorsal lamina; 10, peribranchial space; 11, mantle; 12, heart; 13, anus; 14, intestine; 15, stomach; 16, testis; 17, ovary.

The heart (12) is ventral in position and lies in a pericardial space, which alone represents the only part of the coelom in the adult. The contractions of the heart change their direction regularly, passing first for a time from one end of the heart to the other and then after a moment of rest in the opposite direction, a peculiarity which occurs only in tunicates. The blood circulates mainly in spaces in the mantle and the tunic and in the walls of the branchial sac. The nervous system consists, first, of a simple dorsal ganglion (4) which lies in the mantle near the mouth, and, second, of nerves which radiate from it. Simple eyes and tactile organs are present in many species. Tunicates are mostly hermaphroditic, the gonads being either single or paired and the genital ducts opening into the cloacal chamber. Asexual reproduction is very general, and in many species may lead to the formation of colonies. The adult structure of the *Larvacea* as well as the embryonic and larval structure of the *Ascidiacea* present many points of resemblance to *Amphioxus* and the lower vertebrates, indicating a relationship between these animals and tunicates. This resemblance consists in the main in the presence of a tubular, dorsal central nervous system, a notochord, a ventral heart, and the pharyngeal respiration.

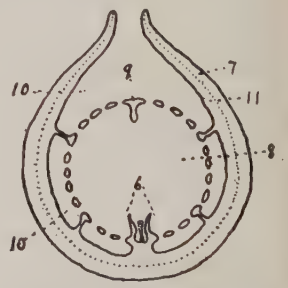

Fig. 999—Diagram of a cross section of an ascidian (Boas). Explanations as in Fig. 998.

History.—Ascidians have been known since the time of Aristotle, but it was not until the first years of the last century that Cuvier, Savigny, and Lamarck first accurately described them. The name *Tunicata* was introduced by the latter author in 1816. *Salpa* was first described by Forskal in 1775, and in 1819 its interesting life history was first made known by the German poet Chamisso. Steenstrup in 1842 more fully described this and first called it an alternation of generations. It was in 1826 that Milne-Edwards discovered and correctly interpreted the ascidian tadpole, while Kowalevsky in 1866 and 1871 published his celebrated memoirs giving the complete embryology of the animals and demonstrating the common relationship of tunicates and vertebrates. Up to that time the tunicates were almost universally classified with mollusks. Milne-Edwards had, however, in 1841 placed them in the *Molluscoidea*, a phylum he created to contain them and the *Bryozoa*.

Tunicates are all marine animals, the ascidians being sessile and the others pelagic. The number of species is about 1,300, which are grouped in 3 classes.

Key to the classes of *Tunicata:*

a_1 Pelagic animals.
  b_1 Animals minute and with a long tail.....1. LARVACEA
  b_2 Animals not minute, and more or less cylindrical or flattened .....2. THALIACEA
a_2 Sessile (except the *Pyrosomidae*), sac-shaped animals.. ..... 3. ASCIDIACEA

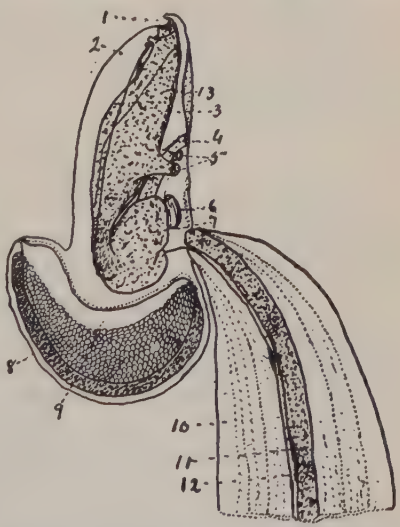

Fig. 1,000—Diagram of an appendicularian (*Oikopleura*) (Delage et Hérouard). 1, mouth; 2, trunk; 3, pharynx; 4, anus; 5, stigmata; 6, heart; 7, stomach; 8, ovary; 9, testis; 10, basal portion of tail; 11, notochord; 12, principal nerve; 13, endostyle.

CLASS 1. LARVACEA.*

The appendicularians (Fig. 1,000). Minute, transparent, free-swimming tunicates in which the body consists of a trunk (2) and a long tail (10), having essentially the same organization as the larval ascidian. The trunk contains the large pharynx and the viscera. The tail is a solid structure, the axis of which is the notochord (11); dorsal to this structure is the principal nerve (12) and on each side of it a broad muscle band. The tail is twisted 90°, so that its dorsal side lies at the

* "Études sur les Appendiculaires du détroit de Messine," by H. Fol, Mém. Soc. Phys. Hist. nat., Génève, Vol. 21, 1872.

left and its ventral side at the right. The mouth (1) is at the forward end and opens into the pharynx (3), from which the two ventro-lateral stigmata (5) open directly to the outside back of the anus, there being no peribranchial cavity and no cloacal pore. Most species are hermaphroditic, the gonads lying in the hinder part of the trunk. The tunic or "house" is a transparent envelope of large size, being sometimes many times the size of the body, which is secreted by certain large ectoderm cells called oikoplasts. Within this tunic (Fig. 1,001) the animal can move about freely: it is shed periodically and often, and contains no cellulose.

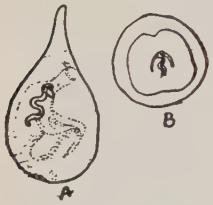

Fig. 1,001—Appendicularians in their tunics (Delage and Hérouard). A, *Oikopleura cophocerca;* B, *Appendicularia sicula.*

The appendicularians are found in all seas, being usually more numerous at a distance from the continents. Most species live near the surface, but a few have been obtained at considerable depths.

The class contains 2 families and more than 40 species.

Key to the families of *Larvacea:*

a_1 Endostyle present.....1. APPENDICULARIIDAE
a_2 Endostyle absent.....2. KOWALEVSKIIDAE

FAMILY 1. APPENDICULARIIDAE.

Pharynx with endostyle, from the forward end of which peripharyngeal ridges run dorsally and posteriorly and unite near the œsophageal opening; heart present: 8 genera and over 30 species.

Key to the genera of *Appendiculariidae* here described:

a_1 Trunk short and more or less oval.
b_1 Tail about twice as long as trunk.....1. APPENDICULARIA
b_2 Tail several times as long as trunk.....2. OIKOPLEURA
a_2 Trunk very long.....3. FRITILLARIA

1. APPENDICULARIA Fol. Trunk short, compressed anteriorly; tail 2 or 3 times as long as broad and twice as long as the trunk; endostyle straight or slightly curved; intestine turned to the right and bent round the very large vesicular rectum; anus on the right; ovary round, surrounded by the horseshoe-shaped testis: 1 certain and several uncertain species.

A. sicula Fol. (Fig. 1,001,B). Mediterranean Sea and Atlantic Ocean.

A. longicauda Vogt. Long Island Sound to Massachusetts Bay.

2. OIKOPLEURA Mertens (Fig. 1,000). Trunk oval; tail from 2 to 6 times as long as broad and from 2 to 4 times as long as the trunk; digestive tract very large, with a curved œsophagus and a bilobed stomach; gonads very large; testis usually paired and one on each side of the median ovary: 14 species.

O. flabellum Huxley (*O. huxleyi* Ritter). Length up to 12 mm., of which 10 mm. is tail: Pacific and Atlantic Oceans.

O. cophocerca Gegenbauer (Fig. 1,001, A). Length 11 mm., of which 8 mm. is tail; a long double row of cells on right side of tail: Mediterranean Sea.

3. **Fritillaria** Fol. Trunk very long, usually constricted near the middle and with an extensive dorsal ectodermal fold which covers it like a cowl; tail about 1.5 times as long as the trunk and 2.5 times as

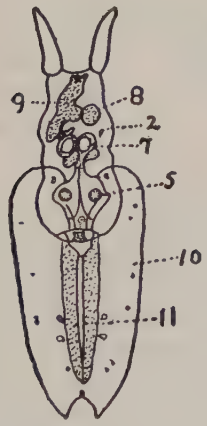

Fig. 1,002

Fig. 1,003

Fig. 1,002—*Fritillaria furcata* (Fol). Explanations as in Fig. 1,000.
Fig. 1,003—*Kowalevskia tenuis* (Fol).

long as broad; endostyle bent; tunic absent or not well developed; digestive tract small, confined to the middle of the trunk; ovary spherical, testis large and saccular, in hinder part of trunk, both usually single: about 8 species.

F. furcata (Vogt) (Fig. 1,002). With long posterior processes; tail forked at its extremity: Mediterranean Sea; North Atlantic.

Family 2. KOWALEVSKIIDAE.

Pharynx without endostyle and periphryngeal ridges; heart absent: 1 genus and 2 species.

Kowalevskia Fol. Trunk elongate, cylindrical; tail about 7 times as long as trunk and lanceolate, running to a point behind; tunic very thin and delicate; œsophagus very wide; ovary spherical; testes reniform: 2 species.

K. tenuis Fol. (Fig. 1,003). Mediterranean Sea and Atlantic Ocean.

Class 2. THALIACEA.

The salpas (Fig. 1,004). Pelagic, transparent tunicates, more or less cylindrical in shape, with a large oral opening (1) at one end of the body and a cloacal opening (12) at the other. The body wall consists of a cellulose tunic (4) and a mantle, the latter containing a number of conspicuous, more or less ring-shaped muscle bands (11), by the contraction of which water is expelled from the cloacal opening as the animal moves forwards. The cavity of the body is divided by a respiratory partition (3) containing slits or stigmata (*Doliolum*) or consisting simply of a ciliated bar (*Salpa*), into two chambers, the anterior or pharyngeal (5) and the posterior or cloacal (9), through which the water streams. Endostyle (6) and dorsal lamina (14) are present. The principal viscera lie embedded in the mantle on the ventral side of the body (8), forming there in many species a small, compact, usually highly colored mass called the nucleus. The principal ganglion (2) lies in the dorsal wall of the pharyngeal chamber. Immediately above it in *Salpa* is a simple eye. Beneath the ganglion is a subneural gland.

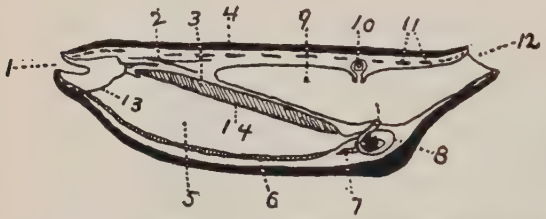

Fig. 1,004—Diagram of a salpa (Cambridge Natural History). 1, mouth; 2, brain; 3, respiratory partition; 4, test; 5, pharynx; 6, endostyle; 7, heart; 8, nucleus; 9, cloacal cavity; 10, ovary; 11, muscle bands; 12, cloacal opening; 13, peripharyngeal ridge; 14, dorsal lamina; 15, salpa chain.

The *Thaliacea* have what is usually called an alternation of generations, a solitary generation alternating with an aggregated one, although in *Salpa* at least it is not strictly so. In the solitary form of *Salpa* a ventral, posterior stolon arises, on which buds appear which are destined to become the aggregated generation. Near the base of the stolon the solitary individual bears a mass of germ cells, some of which are received by the buds as they arise. Thus the buds, and the animals of the aggregated generation they grow into, serve merely as nurses for the embryos arising from these germs which have been received from the solitary individual. The aggregated individuals form the *Salpa* chain and often remain attached together long after they have left the parent. The class contains about 40 species, grouped in 2 orders.

Key to the orders of *Thaliacea:*

a_1 Respiratory partition plate-like.....1. Multistigmatea
a_2 Respiratory partition rod-like.....2. Astigmatea

Order 1. MULTISTIGMATEA.*

Body barrel-shaped, with a thin tunic and with muscle bands forming complete rings; openings lobed and at opposite ends of the body; respiratory partition with 2 rows of stigmata; life history including 3 types of asexually produced individuals and a fourth type arising from a fertilized egg: 3 genera.

Doliolum Quoy and Gaimard. Sexual generation with 8 muscle bands and with 12 oral and 10 cloacal lobes; first asexual generation, with 9 muscle bands and 10 oral and 12 cloacal lobes. From the hinder end of this individual grow a dorsal protuberance and a ventral stolon; the buds, originating on the latter, migrate to the former, which becomes long and tail-like and bears 5 rows of buds, of which the median row becomes detached to form the next asexual generation. The animals of this generation are similar to the sexual generation except that they have no sexual organs and have a ventral stolon which produces buds which become detached and grow into the sexual generation. About 13 species are known, mostly in the warmer oceans.

D. denticulatum Quoy and Gaim. Sexual generation with a bent respiratory partition which has about 40 stigmata on each side; digestive canal straight; length 3 mm.: Atlantic Ocean and Mediterranean Sea.

Order 2. ASTIGMATEA.†

Body usually somewhat flattened dorsoventrally, with terminal or subterminal oral and cloacal openings; tunic thick; muscle bands do not form complete rings in many species; respiratory partition reduced to a ciliated bar which runs diagonally from the dorsal body wall to the œsophagus in the ventral; life history including 2 types of individuals, a solitary and an aggregated, which alternate with each other: 2 genera and about 25 species.

Key to the genera of *Astigmatea:*

a_1 Nucleus usually present, when absent muscle bands numerous; salpa chain straight.....1. Salpa
a_2 No nucleus present; salpa chain often circular.....2. Cyclosalpa

1. Salpa Forskal. Digestive tube usually bent on itself and contained in the nucleus; 1 to 5 embryos formed; chain double: about 18 species; in all the warmer seas.

* See "Cyclomyaria et Pyrosomida," by G. Neumann, Das Tierreich, 1913.
† See "The Genus Salpa," by W. K. Brooks and M. M. Metcalf, Mem. Johns Hop. Univ., Vol. 2. 1893. "Desmomyaria," by J. E. W. Ihle, Das Tierreich, 1912.

S. fusiformis Cuvier (Fig. 1,005). Solitary form (*S. fusiformis* Cuv.) a flattened cylinder and with 9 muscle bands and 2 short spinose projections at hinder end and 4 to 8 cm. long; aggregated form (*S. runcinata* Chamisso) with 6 muscle bands, elliptical and 14 to 60 mm. long: cosmopolitan.

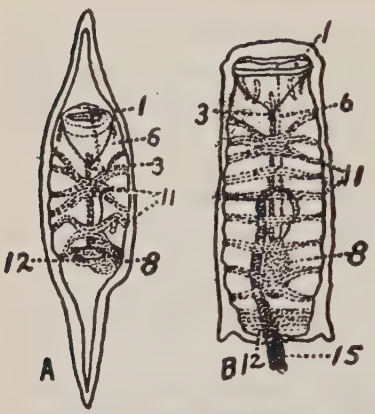

Fig. 1,005—*Salpa fusiformis*. A, aggregated form; B, solitary form (Cambridge Natural History). Explanations as in Fig. 1,004.

S. (*Thalia* Blumenbach) **democratica** Forsk. (*Salpa caboti* Desor) (Fig. 1,006). Solitary form (*S. democratica* Forsk.) ovoid, with 2 long posterior projections and up to 24 mm. long; aggregated form (*S. mucronata* Forsk.) ovoid, pointed behind and up to 15 mm. long; nucleus blue in both forms: cosmopolitan; often appearing in immense numbers off the coast of New England; the commonest species.

S. (*Pegea* Savigny) **confœderata** Forsk. Solitary form short and wide, pointed behind; 4 muscles, which are confined to the back; length 4 to 12 cm.; aggregate form (*S. scutigera* Cuv.) cylindrical, often reddish in color, with 4 muscles; length 7 to 15 cm.: cosmopolitan; aggregate form often common; solitary form very rare.

S. (*Jasis* Lahille) **zonaria** (Pallas). Solitary form elongate, very firm and hard, with 5 very broad muscles and 1 narrower posterior muscle on the dorsal surface, and up to 6 cm. long; aggregate form elongate, ovoid, pointed behind, about 24 mm. long; very firm: in all warmer seas; Woods Hole; Arctic Seas.

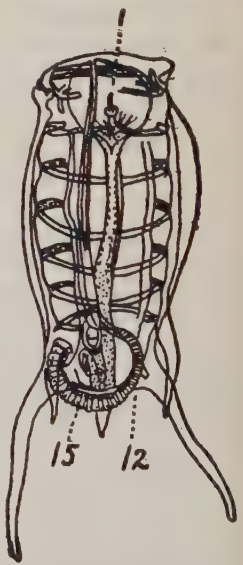

Fig. 1,006—*Salpa democratica*—solitary form (Vogt and Jung). Explanations as in Fig. 1,004.

2. **Cyclosalpa** Blainville. Digestive tube straight or curved, running antero-posteriorly and not coiled up to form a nucleus; salpa chain often circular; in other respects like Salpa: 6 species.

C. affinis (Chamisso). Aggregated form about 7 cm. long, with ventral hatchet-shaped organ of attachment; apertures terminal; solitary form 5 to 10 cm. long, with no longitudinal muscles: Mediterranean; Atlantic and Pacific Oceans; often very plentiful.

Class 3. ASCIDIACEA.*

The ascidians. Sac-shaped, mostly sessile and either simple or compound tunicates with oral and cloacal openings usually placed near together, each at the end of a contractile projection called the siphon (Fig. 998). The cellulose tunic is usually thick and tough, but in some forms it is gelatinous or transparent, and is often rough and warty on the outside. Both openings can be closed by sphincter muscles and are often provided with a number of sensory lobes bearing in some cases pigment spots. The branchial sac (8) is very large and its entire wall is pierced by more or less regular series of slits or stigmata, giving it a lattice-like appearance. Its upper margin is surrounded by a circle of tentacles, which thus lie just back of the mouth. Endostyle (6), peribranchial band (5), and dorsal lamina (9) are present. On each side of the branchial sac is the peribranchial space, into which the respiratory water as well as the discharges from the genital and digestive organs are poured, and which communicates with the outside through the cloacal opening (Fig. 999, 10). The œsophagus, stomach, and the short intestine are either at the side of or beneath the branchial sac. The anus opens into the peribranchial chamber near the cloaca or into the cloaca itself. The principal ganglion (4) is situated between the two siphons in the mantle and adjacent to it is the subneural gland (3), which is supposed to be homologous to the hypophysis of vertebrates. A duct joins this gland with the pharynx, the opening being at the end of a projection called the dorsal tubercle. A ductless kidney or scattered renal cells in the bend of the intestine contain uric acid crystals.

Ascidians are hermaphroditic, the gonads lying close together. From the egg is hatched a long-tailed larva which has the appearance and general structure of an appendicularian. This larva attaches itself to some fixed object by three papillae at the forward end, and a complex metamorphosis proceeds, during which the tail is absorbed, the peribranchial chamber develops, and the body assumes the spherical or cylindrical shape of the adult.

Ascidians are either simple or colonial and with the exception of the *Pyrosomidae* are all sessile, being attached usually to rocks or seaweed. The colonial forms arise by a process of budding from one another and form incrusting or erect masses on shells, seaweed, etc. Several species are used for food, large numbers being brought into the fish markets of

* See "Some Ascidians from Puget Sound," by W. E. Ritter, Ann. N. Y. Acad. Sci., Vol. 12, p. 589, 1909. "The Ascidians of Bermuda," by W. G. Van Name, Trans. Conn. Acad., Vol. 11, p. 325, 1902. "Mosaic Development in Ascidian Eggs," by E. G. Conklin, Jour. Ex. Zool., II, p. 145, 1905. "The Simple Ascidians from the North Eastern Pacific," etc., by W. E. Ritter, Proc. U. S. Nat. Mus., Vol. 45, p. 427, 1913.

Marseilles and other Mediterranean cities. Over 1,200 species of ascidians are known, grouped in 2 or 3 orders.

Key to the orders of *Ascidiacea:*

a_1 Sessile ascidians.
b_1 Simple ascidians, or forms loosely connected by a stolon.
1. ASCIDIAE SIMPLICES
b_2 Colonial ascidians, forming compact masses.....2. ASCIDIAE COMPOSITAE
a_2 Pelagic ascidians.....3. ASCIDIAE LUCIAE

ORDER 1. ASCIDIAE SIMPLICES.*

Solitary ascidians, or when colonial always loosely connected and with the tunics separate and distinct, and not fused together; never free-swimming: about 4 families and over 500 species.

Key to the families of *Ascidiae simplices:*

a_1 Individuals not permanently joined together.
b_1 Body more or less spherical and often stalked.
c_1 Colors dull; surface often incrusted with sand.....1. MOLGULIDAE
c_2 Colors often bright, surface usually free from sand.....2. CYNTHIIDAE
b_2 Body cylindrical, elongate and not stalked.....3. ASCIDIIDAE
a_2 Individuals joined by creeping stolons.....4. CLAVELINIDAE

FAMILY 1. MOLGULIDAE.

Body spheroidal, seldom stalked, with dull, usually gray colors and often incrusted with sand or mud; mouth with 6 outer lobes and with branched inner tentacles; cloaca with 4 lobes; intestine usually on the left; kidney and heart on the right side of the branchial sac; reproductive organs either paired or not, in latter case either on right or left side; animals solitary, often in sand or mud: about 14 genera and over 100 species.

Key to the genera of *Molgulidae* here described:

a_1 Body not stalked.
b_1 Branchial sac with longitudinal bars.....1. MOLGULA
b_2 No such bars.
c_1 No corkscrew-shaped infundibula on branchial sac.....2. EUGYRA
c_2 Such infundibula present.....3. BOSTRICHOBRANCHUS
a_2 Body stalked.....4. RHIZOMOLGULA

1. MOLGULA Forbes. Siphons usually long and very contractile; tunic thin and more or less transparent, although often incrusted with sand and dirt; gonads paired and usually hermaphroditic; branchial sac large, with 6 or 7 longitudinal folds or bars: cosmopolitan; 50 or more species, some of which are not fixed, 10 American.

* See "Simple Ascidians of the Coast of New England," etc., by W. Van Name, Proc. Bost. Soc. Nat. Hist., Vol. 34, 1912.

Key to the species of *Molgula* here described:

a_1 Siphons contiguous at the base.
  b_1 Siphons not swollen at the base.....M. MANHATTENSIS
  b_2 Siphons swollen at the base.....M. PELLUCIDA
a_2 Siphons not contiguous.
  b_1 Siphons short.....M. ARENATA
  b_2 Siphons long.....M. PAPILLOSA

M. manhattensis (DeKay) (Fig. 1,007). Body globose or ovoid; external surface corrugated, usually covered with foreign matter; siphons contiguous; length 25 mm.: on rocks or eel grass, often in clusters, in shallow water below low tide lines; from North Carolina to Casco Bay; abundant.

Fig. 1,007 *Molgula manhattensis* (Verrill).

M. arenata Stimpson. Body globose, often compressed, covered with sand which adheres tightly; siphons short, not contiguous; length 20 mm.: on sand and gravel in shallow water; in Long Island and Vineyard Sounds.

M. pellucida Verrill. Body globose, with a smooth, translucent tunic to which sand does not adhere; siphons contiguous, long and diverging and swollen at the base; length 25 mm.: on sand in shallow water from North Carolina to Massachusetts Bay.

M. papillosa Verr. Body globose, often compressed, covered with sand or dirt; siphons not contiguous, long, and diverging; length 10 mm.: on sand and gravel in 10 to 20 fathoms; from Vineyard Sound northwards; common towards the north.

2. **Eugyra** Alder and Hancock. Branchial sac without longitudinal bars; a single hermaphroditic gonad present, which is on the left in the bend of the intestine: 8 species; in shallow water.

E. pilularis Verr. (Fig. 1,008). Body globose, covered with mud or fine sand; siphons close together, slender, and as long as the body when extended; diameter up to 8 mm.: in 10 to 20 fathoms from Vineyard Sound northwards, in mud or fine sand, where it is locomotory; often abundant.

Fig. 1,008 *Eugyra pilularis* (Verrill).

3. **Bostrichobranchus** Traustedt. Like *Eugyra* but with corkscrew-shaped infundibula in the meshes of the branchial sac: 2 species.

B. molguloides Metcalf. Body 3 cm. in diameter and not attached: Woods Hole; on muddy bottoms.

4. **Rhizomolgula** Ritter. Body ovoid, prolonged posteriorly in a stalk which may be as long as or longer than the body and ends in a number of root-like branches; kidney and the single gonads on the left side: 4 species; in North Pacific and Atlantic Oceans.

R. ritteri Hartmeyer. Body globose, wider than long, 8 mm. long with a stalk of same length: Baffin Bay; in shallow water.

Family 2. CYNTHIIDAE.

Body always attached, spherical or elongate, with a tough leathery tunic which is opaque, often brightly colored, and usually not covered with sand; siphons short and usually four-lobed; inner tentacles either simple or branched; branchial sac large, with 4 or more longitudinal folds or bars on each side; intestine on the left side; distinct kidney absent, its place taken by scattered renal cells; gonads hermaphroditic: several hundred species.

Key to the genera of *Cynthiidae* here described:

a_1 Body not stalked or with a short stalk.
  b_1 Oral tentacles simple and filiform.....1. Styela
  b_2 Oral tentacles branched.....2. Cynthia
a_2 Body with a long stalk.....3. Boltenia

1. Styela Fleming. Body sessile; branchial sac with not more than 4 ridges on each side; tentacles simple and filiform: cosmopolitan; over 75 species.

S. partita (Stimpson) (*S. aggregata* var. *americana* Metcalf) (Fig. 1,009). Body somewhat flattened and attached by a broad base; surface not sulcated, hard, wrinkled, dark brown in color; siphons square, elevated, each aperture marked by alternating triangles of white and purple; length 25 mm.; breadth 12 mm.: Massachusetts Bay to North Carolina; in shallow water; common, occurring in groups.

Fig. 1,009—*Styela partita* (Verrill).

2. Cynthia Savigny. Body sometimes with a short stalk; branchial sac with 6 to 12 longitudinal ridges on each side; dorsal lamina a serrate or fringed membrane; tentacles branched; gonad paired: 100 species.

C. castaneiformis Drasche. Peduncle about as long as body but variable in length; body more or less globose in form and hirsute; orifices prominent; tentacles 50; branchial ridges 8 on a side; length 35 mm.: Puget Sound and southerly; common.

Fig. 1,010—*Cynthia carnea* (Verrill).

C. carnea Verrill (Fig. 1,010). Body flat and disc-like, oval, and deep red in color, attached by a very broad base; siphons small; length 12 mm.: Martha's Vineyard to Labrador; in shallow water; often very common.

C. pyriformis (Rathke). Sea peach. Body globose or elliptical, often attached by a narrow base; surface velvety and pink, red, or yellowish in color; length 75 mm. or less; width 30 mm.; siphons cylin-

drical, large, and prominent: Massachusetts Bay to Greenland, in clear, shallow water; common towards the north; Norway.

C. superba Ritter. Body large, bright red in color, pear-shaped, with the broad end at the base, 15 cm. long and 6.5 cm. thick; siphons prominent, not contiguous: Puget Sound; rare.

C. (*Halocynthia* Verr.) **echinata** (L.). Body globose; surface wrinkled, covered with fine fibers and elevated tubercles, each bearing a stellate cluster of about 6 yellow bristles; diameter 25 mm.; color red: Martha's Vineyard to Greenland; in shallow water; common towards the north; Europe.

3. **Boltenia** Savigny. Body globose or elliptical and attached by a long stalk which proceeds from the antero-ventral side of the body; orifices not terminal but lateral in position, each being provided with 4 lobes; oral tentacles branched; more than 8 longitudinal ridges in branchial sac: about a dozen species; in the colder seas.

B. rubra Stimpson. Sea potato (Fig. 1,011). Body slightly compressed and tapering to the slender stem; color red; surface rough; length of body 4 cm., of stem 26 cm.: Cape Cod northwards, in 2 to 14 fathoms; abundant.

Fig. 1,011
Boltenia rubra
(Gould).

Family 3. ASCIDIIDAE.

Body more or less cylindrical, with a gelatinous, transparent tunic; openings lobed; oral tentacles simple; branchial sac without well-developed longitudinal bars; gonads hermaphroditic and unpaired: species numerous; about 10 genera.

1. **Ascidia** L. Body elongate; branchial sac extending to the base with the intestine on its left side; oral opening with 8 and cloacal opening with 6 lobes: numerous species.

Fig. 1,012
Ciona intestinalis
(Gould).

A. atra Lesueur (*A. nigra* Savigny). Body ovate, elongate, with abundant blue-black pigment in the tunic and many internal organs; length 7 cm.; diameter 3 cm.: Bermuda; West Indies.

2. **Ciona** Savigny. Body cylindrical and elongate; siphons more or less extended, oral siphon with 8 and cloacal siphon with 6 lobes; intestine beneath the branchial sac, which does not extend to the base: 10 species.

C. intestinalis (L.) (*C. tenella* Stimpson) (Fig. 1,012). Body more or less transparent, 10 cm. long or less and 20 mm. wide, adhering by the base, sometimes yellowish in color: Long Island Sound to Labrador, on stones, shells, etc.; common towards the north.

Family 4. CLAVELINIDAE.

Body elongated and joined by means of creeping stolons with other individuals, forming thus a branched colony with a common blood system, or rarely embedded in a common gelatinous tunic; apertures simple, rarely lobed: about 8 genera and 28 species.

1. Clavelina Savigny. Zooids elongate, made up of 2 regions, a thorax and an abdomen, joined by stolons with one another; apertures simple: about 8 species.

C. oblonga Herdman. Zooids club-shaped, 30 mm. long or less; tunic thick and transparent; branchial sac with about 15 rows of stigmata; tentacles about 20 in number, short and stout: Bermuda; common.

2. Perophora Lister. Body compact and not composed of 2 regions, the intestine being at the side of the branchial sac; both apertures six-lobed.

P. viridis Verrill. Body small, oval, 3 mm. long, greenish or yellowish in color: Vineyard Sound; common; often covering piles, seaweed, or stones near low-water mark.

Order 2. ASCIDIAE COMPOSITAE.*

Composite, colonial ascidians, the members of a colony being joined by a common tunic and often possessing a common cloaca, and arising from one another by a process of budding; individuals often elongate and consisting of 2 or 3 distinct divisions, called thorax, abdomen, and post-abdomen (Fig. 1,014): about 7 families.

Key to the families of *Ascidiae compositae* here described:

a_1 Body without division into thorax and abdomen; mouth not lobed. ..... 1. Botryllidae
a_2 Body composed of 2 or 3 divisions; mouth with usually 6 lobes.
  b_1 Colony not incrusting.
    c_1 Colony without common cloacal openings ..... 2. Distomidae
    c_2 Colony with common cloacal openings ..... 3. Polyclinidae
  b_2 Colony incrusting ..... 4. Didemnidae

Family 1. BOTRYLLIDAE.

Colony either thin and crust-like or thick and fleshy, consisting of individuals in groups, each group with a common cloaca; no division into thorax and abdomen; branchial sac without longitudinal folds, usually with 3 inner longitudinal bars; male and female gonads separate, on both sides of body: 5 genera with about 80 species.

Key to the genera of *Botryllidae* here described:

a_1 Individuals in circular, star-shaped, or elliptical groups ..... 1. Botryllus
a_2 Individuals not in regularly arranged groups ..... 2. Botrylloides

* See "Compound Ascidians of the Coast of New England," etc., by W. Van Name, Proc. Bost. Soc. Nat. Hist., Vol. 34, 1910.

1. Botryllus Gaertner. Colony thin and crust-like and embedded in a common gelatinous tunic, the individuals being in circular, stellate, or elliptical groups, in each of which they are arranged radially around a common cloacal opening; incurrent opening widely separated from the cloacal and near the periphery of the group; oral tentacles not branched and few in number: about 24 species; principally in North Atlantic and Mediterranean, in shallow water.

B. schlosseri (Pallas) (*B. gouldi* Verrill) (Fig. 1,013). Colonies massed thickly together on seaweed, stones, etc., forming gelatinous, black or purplish incrustations sometimes 10 cm. or more in diameter, a colony being made up of many groups, each group consisting of from 5 to 10 individuals and 3 to 6 mm. in diameter: Long Island Sound and northwards; very common; Europe.

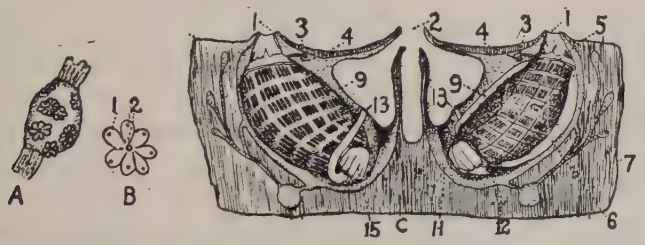

Fig. 1,013—*Botryllus schlosseri.* A, a colony on a seaweed containing 7 groups of individuals (Gould); B, diagram of a single group of individuals; C, diagram of two individuals of a group with the common cloacal opening, the right-hand individual in sagittal section (Delage and Hérouard). Explanations as in Fig. 998.

2. Botrylloides Milne-Edwards. Colony thin and crust-like, the individual animals lying perpendicular to the surface and usually not arranged in definite groups; the individuals lie along cloacal canals which meet and open to the outside through a common cloacal pore: over 2 dozen species.

B. nigrum Herdman. Colony up to 7 cm. in diameter, very variable in color, usually purplish or blackish; individuals about 1.5 mm. long: Bermuda; in shallow water; common on stones and seaweed.

Family 2. DISTOMIDAE.

Colony thick, sometimes stalked, usually embedded in a common tunic; individuals consisting of thorax and abdomen, the viscera being beneath the branchial sac, which is without internal longitudinal bars or folds; openings each with 6 lobes: 10 genera, with about 80 species.

Distoma Gaertner. Colony thick and fleshy, with the individuals often in groups; intestine very long; branchial sac short: about 20 species.

D. clarum Van Name. Colony jelly-like, transparent, 12 mm. in width and half as thick; individuals lying at all angles to surface, white

in color with orange intestine: Bermuda; common along the shore and on the reefs.

Family 3. POLYCLINIDAE.

Colony variable in shape but usually massive, sometimes stalked, and enclosed in a common tunic; individuals elongate, composed of 3 regions, sometimes in groups; incurrent opening with 6 or 8 lobes; budding by division of the post-abdominal body region which contains the gonads, the heart in the pericardium and the epicardium, which is a tubular prolongation of the pharyngeal sac (Fig. 1,014): about 20 genera and over 150 species.

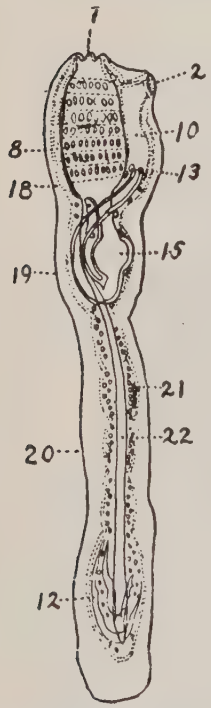

Fig. 1,014
Diagram of Amaroucium (Bronn). 18, thorax; 19, abdomen; 20, postabdomen; 21, blood space; 22, epicardium, a prolongation of the pharyngeal sac into the postabdomen. Other explanations as in Fig. 998.

Amaroucium Milne-Edwards. Colony usually massive, more or less gelatinous or cartilaginous in consistency; individuals very much elongated and usually in irregular groups: about 60 species, most of which occur in shallow water.

A. pellucidum (Leidy). Colonies large, complex, consisting of many groups of elongate zooids, each group having a common cloacal opening and all enclosed in a common gelatinous, translucent tunic; colony up to 15 cm. in diameter; separate zooids up to 25 mm. long; stomach bright orange in color: North Carolina to Vineyard Sound; very common in shallow water.

A. stellatum Verrill. Colonies large, often in form of thick vertical plates which may be 60 cm. long, 15 cm. high, and 25 mm. thick, enclosed by a common gelatinous tunic, and called "sea pork" by fishermen; color pale bluish or pinkish; zooids arranged in stellate clusters containing from 6 to 20 individuals each; branchial sac and intestine orange: very common from North Carolina to Cape Cod and northwards.

A. constellatum Verr. Colony thick, often incrusting, with a smooth surface, forming hemispherical crusts on piles, rocks, etc.; color orange or pink; zooids arranged in irregular stellate or elliptical groups: Long Island and Vineyard Sounds and northwards.

Family 4. DIDEMNIDAE.

Colony incrusting, sometimes thick and massive, and contained in a common tunic, in which are calcareous spicules; zooids arranged in com-

plex branching systems of small size, with body composed of 2 portions; incurrent opening 6-lobed: 9 genera, with numerous species.

Didemnum Girard. Colony usually thick, opaque, often leathery; calcareous spicules stellate in form; zooids small, with 3 rows of stigmata in the branchial sac: numerous species.

D. orbiculatum Van Name. Colonies thin, 25 mm. wide and 2 mm. thick, gray in color, with numerous spicules which tend to conceal the zooids: common on the underside of stones near low water in Bermuda.

D. lutarium Van Name (*Leptoclinum albidum* Verrill; *L. luteolum* Verr.). Colony forms a thin incrustation up to 30 cm. in diameter, covering stones, shells, etc., and white or pink in color, with an uneven surface by reason of the numerous calcareous spicules present: Long Island Sound to Labrador; common; in shallow water.

Order 3. ASCIDIAE LUCIAE.*

Animals colonial, free-swimming, and enclosed in a common tunic; colony cylindrical, conical or flattened in shape with one open end; zooids arranged in a single layer, perpendicular to the surface, the incurrent openings being on the outer and the cloacal openings on the inner surface of the cylindrical colony; projecting from the outer surface are often long finger-like processes of the tunic, and at the forward end of the branchial sac of each zooid are paired phosphorescent organs; the colony swims with the closed end in advance as the result of the streaming of water out of the open end: 1 genus, the species of which are noted for their brilliant phosphorescence.

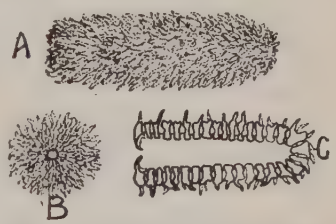

Fig. 1,015—*Pyrosoma atlanticum* (Cambridge Natural History).

Pyrosoma Péron. With the characters of the order; colony cylindrical or flattened: 8 species, in tropical seas.

P. atlanticum Pér. (Fig. 1,015). Colony conical, 3 or 4 cm. in diameter, and 25 cm. or more in length, although usually much smaller; color greenish, pinkish, or yellowish: in the tropical Atlantic.

Subphylum 3. LEPTOCARDIA.* (Cephalochordata; Amphioxus.)

Elongate, fish-shaped *Chordata,* in which the notochord extends the entire length of the body. The body is laterally compressed and pointed

* See "Cyclomyaria et Pyrosomida," by G. Neumann, Das Tierreich, 1913.

† See "Amphioxus and the Ancestry of Vertebrates," by A. Willey, 1894. "A Revision of the Genera and Species of the Branchiostomidae," by J. W. Kirkaldy,

at both ends, with conspicuous muscle segments (myotomes) and a dorso-ventral fin at the hinder end. There is no head, the mouth, which is surrounded by long cirri, being ventral in position, skewed a little to the left, and just back of the pointed snout. The anus is near the hinder end, a little to the left of the median line. The anterior portion of the digestive tract forms the extensive pharynx, the walls of which are perforated by numerous paired gill slits. Through these, respiratory water, which is taken in at the mouth, streams into a peribranchial chamber, which communicates with the outside through a median ventral pore in the hinder half of the body. In the mid-dorsal as well as the mid-ventral line of the pharynx is a ciliated groove, the latter of which is homologous to the endostyle of tunicates. Back of pharynx the straight intestine passes to the anus, the only digestive gland being the liver, a long diverticulum which extends from the intestine forwards into the peribranchial chamber. The notochord is a cylindrical rod which forms the axial skeleton of the body, through which it extends from tip to tip, lying just above the digestive tube. Above it lies the spinal cord, which possesses a central canal, the anterior end of which expands to form a vesicle. Metameric pigment spots, an olfactory pit at the anterior end, and bristle-tipped cells in the skin are the organs of special sense.

The vascular system consists of a ventral longitudinal blood vessel which lies beneath the intestine and pharynx, breaking up into capillaries (portal system) over the liver, a dorsal vessel over the intestine which is double over the pharynx, and lateral vessels connecting these two. The lateral branches in the wall of the pharynx become branchial vessels; in the hinder portion of the animal the lateral vessels break up into capillaries on the wall of the intestine. A heart is not present but the anterior portion of the ventral trunk and others of the larger vessels are contractile; the blood is colorless. The excretory system consists of numerous pairs of nephridia which lie above the upper ends of the gill slits and communicate with the peribranchial chamber. The sexes are separate, the gonads being a series of glands which lie along the side of the body opposite the pharynx, projecting into the peribranchial chamber, into which their products are discharged.

Amphioxus was discovered in 1778 by Pallas, who, believing it to be a slug, gave it the name *Limax lanceolatus*. In 1834 Costa gave the animal the generic name of *Branchiostoma*. Two years later Yarrell, not knowing of Costa's work, named it *Amphioxus*, which has been the

Quart. Jour. Mic. Sci., Vol. 37, p. 303, 1895. "Cephalochordata," Camb. Nat. Hist., 1904. "Maldive Cephalochordates," etc., by G. H. Parker, Bull. Mus. Comp. Zool., Vol. 46, p. 39, 1904.

familiar name of the animal ever since. Johannes Müller (1842) recognized its relation to vertebrates, and Kowalevsky (1867) described its embryology and elucidated its relationship to tunicates.

The *Leptocardia* are found in shallow bays in many places in tropical and temperate regions, and bury themselves in an upright position in the sand with the mouth projecting into the water. In America they are found as far north as Chesapeake Bay and in Europe as far as Scandinavia. The class contains a single family and about a dozen species.

Family BRANCHIOSTOMIDAE.

With the characteristics of the class: 3 genera.

1. Branchiostoma Costa (*Amphioxus* Yarrell). Body symmetrical; genital organs on both sides; caudal fin lanceolate: 7 species.

B. lanceolatum (Pallas) (Fig. 1,016). Length about 48 mm.; gonads about 26 pairs: Chesapeake Bay and southerly; Europe; Ceylon.

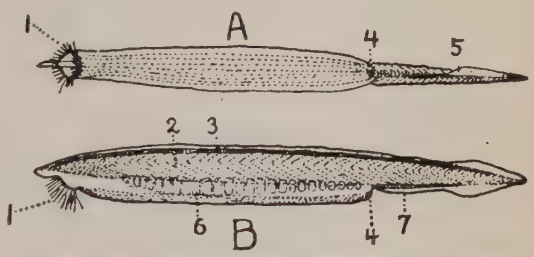

Fig. 1,016—*Branchiostoma lancelatum*. A, ventral aspect; B, left side of body (Cambridge Natural History). 1, oral cirri; 2, muscle segments; 3, dorsal fin; 4, ventral pore of peribranchial chamber; 5, anus; 6, gonads; 7, ventral fin.

B. caribbæum Sundevall. Length 40 mm.; gonads about 26 pairs; differs from *B. lanceolatum* in the slight development of the caudal fin and the shortness of the postanal region: West Indies, North and South America.

B. californiense Cooper. Length 70 mm.; gonads 31 pairs; cephalic region small: California.

2. Asymmetron Andrews. Body asymmetrical; gonads on right side only; ventral fin with no fin rays and poorly developed; a long caudal process present: 7 species.

Fig. 1,017—*Asymmetron lucayanum*—left side of tail (Parker).

A. lucayanum* And. Length 13 mm.; gonads 29 in number, extending from myotomes 15 to 43 inclusive; olfactory pit wanting: Bahamas; Zanzibar.

A. macricaudatum Parker (Fig. 1,017). Length 14 mm.; number of gonads about 26, extending from myotomes 11 to 37 inclusive: Florida coast.

* See "An Undescribed Acraniate," etc., by E. A. Andrews, Stud. Biol. Lab., Johns Hop. Univ., Vol. 5, p. 213, 1893.

LIST OF AUTHORS

This list includes the authors of all specific and generic names and also those of the monographs and treatises herein referred to.

ABBOTT, CHARLES C. (1843—). American naturalist and archæologist resident in Trenton, N. J.

ABILDGAARD, PETER (1740–1808). Danish physician and naturalist.

ADAMS, ARTHUR. English navy surgeon and conchologist; middle of last century; brother of Henry.

ADAMS, CHARLES B. (1814–1853). American conchologist; professor in Amherst.

ADAMS, HENRY. English conchologist; middle of last century; brother of Arthur.

ADANSON, MICHAEL (1727–1806). French conchologist.

AGASSIZ, ALEXANDER (1835–1910). American zoologist resident in Cambridge, Mass.; son of Louis.

AGASSIZ, ELIZABETH C. (d. 1907). American naturalist; wife of Louis.

AGASSIZ, LOUIS (1807–1873). Swiss-American zoologist; professor in Harvard.

ALBERS, JOHANN (b. 1805). German conchologist and physician.

ALDER, JOSHUA (1792–1867). English zoologist and merchant.

ALLMAN, GEORGE JAMES (1812–1898). Irish zoologist; professor in Dublin and Edinburgh.

ANDRES, ANGELO. Italian zoologist; professor in Milan.

ANDREWS, ETHAN A. (1859—). American zoologist; professor in Johns Hopkins.

ANTHONY, JOHN G. American conchologist; middle of last century.

ARCHER, WILLIAM (1830–1897). Irish naturalist and microscopist resident in Dublin.

ARISTOTLE (384 B.C.–322 B.C.). Greek philosopher and naturalist.

ASCANIAS, PETER (1723–1803). Danish zoologist; professor in Copenhagen.

ATKINSON, GEORGE F. (1854—). American botanist; professor in Cornell.

AUDUBON, JOHN JAMES (1780–1851). American ornithologist, naturalist and painter of birds and mammals.

AUDOUIN, JEAN (1797–1841). French zoologist and entomologist; professor in Paris.

AUERBACH, LEOPOLD (b. 1828). German microscopist and protozoologist; professor in Breslau.

BAER, KARL ERNST VON (1792–1876). Russian zoologist; professor in Petrograd.

BAILEY, J. W. English microscopist; middle of last century.

BAIRD, SPENCER F. (1823–1887). American naturalist; secretary of the Smithsonian Institution.

BAIRD, WILLIAM (1803–1872). English zoologist and physician in London.

BAKER, FRANK C. (1867—). American conchologist; Chicago Academy of Sciences.

BANKS, NATHAN (1868—). American entomologist and zoologist; U. S. Department of Agriculture.

BARBAGALLO, PIETRO. Italian parasitologist and physician in Catania.

BARKER, FRANKLIN D. (1877—). American zoologist and helminthologist; professor in the University of Nebraska.

BARNES, DANIEL W. (d. 1818). American conchologist and preacher.

BARTON, BENJAMIN SMITH (1766–1815). American naturalist resident in Philadelphia.

BARTRAM, JOHN (1699–1777). American botanist and naturalist resident in Philadelphia.

BARTRAM, WILLIAM (1739–1823). American botanist and ornithologist; son of John.

BASSI, ROBERTO. Italian veterinary and zoologist; professor in Turin.

BASTIAN, H. CARLTON (1837—). English physician and microscopist; professor in University College, London.

BATESON, WILLIAM (1861—). English zoologist; director of John Innes Horticultural Institution, Merton Park, Surrey.

Batsch, August (1761–1802). German botanist; professor in Jena.
Bavay, Paul. Belgian physician; professor in Brussels.
Beauvois, Palisot de (1755–1820). French naturalist who came to America in 1791 and traveled here extensively.
Beck, Lewis C. (1800–1853). American naturalist and chemist.
Beddard, Frank E. (1858—). English zoologist; Zoological Garden, London.
Beecher, Charles E. (1856–1904). American paleontologist; professor in Yale.
Bell, F. Jeffrey. English zoologist; professor in London.
Bell, Thomas (1792–1880). English zoologist; professor in London.
Bellevue, Fleuriau. French conchologist; first part of last century.
Bellingham, O'Bryen (1805–1877). Irish parasitologist and physician.
Beneden, Pierre Joseph van (1809–1891). Belgian zoologist; professor in Louvain.
Benedict, James E. (1852—). American zoologist; U. S. National Museum.
Benham, William B. (1860—). English zoologist; professor in the University of Otago, New Zealand.
Benson, W. H. Anglo-Indian conchologist; first half of last century.
Berger, Edward W. (1869—). American zoologist; state entomologist of Florida.
Bergh, Ludwig (b. 1824). Danish zoologist.
Berkeley, M. J. (1803–1889). English clergyman and naturalist.
Berlese, Antonio. Italian zoologist and entomologist; professor in Florence.
Best, Robert. American naturalist and physician in Cincinnati; early in the last century.
Beyer, Henry G. (1850—). German-American physiologist and navy surgeon.
Bigelow, Robert P. (1863—). American zoologist; librarian in Massachusetts Institute of Technology.
Bilharz, Theodor (1825–1862). German physician and naturalist; professor in the Medical School in Cairo.
Binney, Amos (1803–1847). American conchologist and physician in Boston.
Binney, W. G. (1833–1909). American conchologist; son of Amos.
Birge, Edward A. (1851—). American zoologist; professor in the University of Wisconsin.
Blackwell, John A. (1790–1881). English arachnologist.
Blainville, Henri de (1778–1850). French zoologist; professor in Paris.
Blanchard, Emile (1820–1900). French zoologist and helminthologist; professor in Paris.
Blanchard, Raphael (1857—). French zoologist and helminthologist; professor in Paris; son of Emile.
Bland, Thomas. American conchologist; middle of last century.
Block, Marcus (1723–1799). German ichthyologist and a physician in Karlsbad.
Blumenbach, Johannes (1752–1840). German zoologist and naturalist; professor in Göttingen.
Boas, J. E. V. (1855—). Danish zoologist; professor in Copenhagen.
Boeck, Axel. Norwegian zoologist and microscopist; middle of last century.
Bohadsch, Johann (1724–1768). Bohemian zoologist; professor in Prague.
Böhmig, Ludwig (1858—). German zoologist; professor in Graz.
Boisduval, Jean (1801–1879). French physician and entomologist in Paris.
Bollman, Charles H. (1868–1889). American zoologist; student in the University of Indiana and assistant in the Fish Commission.
Bolten, Johannes (1718–1796). German naturalist and physician in Hamburg.
Bonaparte, Charles Lucien (1803–1857). French ornithologist; nephew of Napoleon; he lived in Philadelphia from 1822 to 1828.
Bonnier, Gaston (1853—). French botanist; professor in Paris.
Bonz, Christopher Gottlieb. German zoologist of the 18th century.
Boring, Alice M. American zoologist; professor in the University of Maine.
Born, Ignaz von (1742–1791). Austrian conchologist and mineralogist.
Bory de Saint Vincent, Jean (1780–1846). French zoologist, botanist and army officer.
Bosc, Louis (1759–1828). French zoologist and botanist; he traveled in the United States in 1796.
Bouvier, Eugene Louis. French zoologist and entomologist; professor in Paris.
Bowditch, T. Edward. English conchologist; first half of last century.
Bowerbank, John S. (1797–1877). English naturalist and merchant.
Brady, George S. (1832—). English zoologist and physician in Sheffield.

BRANDES, GUSTAV (1862—). German zoologist; director of the Zoological Garden in Dresden.
BRANDT, JOHANN FRIEDRICH (1802–1879). Russian zoologist; professor in Petrograd.
BRAUN, MAX (1850—). German zoologist and helminthologist; professor in Königsberg.
BRODERIP, WILLIAM (1789–1859). English lawyer and naturalist.
BRONN, HEINRICH (1800–1862). German zoologist; professor in Heidelberg.
BROOKS, WILLIAM K. (1848–1908). American zoologist; professor in Johns Hopkins.
BROWN, THOMAS. English conchologist; first half of last century.
BROWNE, PATRICK (1720–1790). Irish naturalist and physician.
BRUGUIÈRE, JEAN (1750–1798). French traveler and zoologist in Montpellier.
BRUNNICH, MARTIN (1737–1827). Danish naturalist; professor in Copenhagen.
BRYANT, ELIZABETH B. American arachnologist; Boston Society of Natural History.
BUCHHOLZ, REINHARDT (1837–1876). German zoologist; professor in Greifswald.
BÜRGER, OTTO (1865—). German zoologist; professor for 8 years in Santiago, Chile.
BURMEISTER, KARL (1807–1861). German zoologist; professor in Halle and later Director of the Natural History Museum in Buenos Ayres.
BURNETT, W. J. (d. 1853). American microscopist.
BUSH, KATHARINE J. (1855—). American zoologist; Peabody Museum, New Haven.
BUSK, GEORGE (1807–1886). English zoologist and paleontologist.
BÜTSCHLI, OTTO (1848—). German zoologist; professor in Heidelberg.

CALKINS, GARY N. (1869—). American zoologist and protozoologist; professor in Columbia.
CALL, R. ELLSWORTH (1856—). American zoologist; teacher in New York City.
CAMBRIDGE, O. P. English clergyman and arachnologist; latter part of last century.
CAMERANO, LORENZO. Italian zoologist; professor in Turin.
CANESTRINI, GIOVANNI. Italian zoologist; professor in Padua.
CARPENTER, PHILIP P. (1820–1877). English conchologist and clergyman in Montreal; a brother of W. B. Carpenter.
CARPENTER, P. HERBERT (d. 1891). English zoologist.
CARPENTER, WILLIAM B. (1813–1885). English physician and naturalist; professor in London.
CARTER, H. J. English zoologist and microscopist; middle of last century.
CARUS, JULIUS VICTOR (1823–1903). German zoologist; professor in Leipzig.
CARY, LEWIS R. (1880—). American zoologist; professor in Princeton.
CASAGRANDI, ODDO. Italian protozoologist and physician in Catania.
CASTLE, WILLIAM E. (1867—). American zoologist; professor in Harvard.
CATESBY, MARK (1680–1759). English naturalist and traveler in America.
CELLI, ANGELO. Italian protozoologist; professor in Rome.
CERTES, MME. ADRIEN. French zoologist; the Musée Guimet.
CHAMISSO, ADALBERT (1781–1839). German poet and naturalist of French birth; custodian of the royal herbarium in Berlin.
CHEMNITZ, JOHANNES (1730–1800). German conchologist and preacher.
CHESTER, WAYLAND M. (1870—). American zoologist; professor in Colgate.
CHILD, CHARLES M. (1869—). American zoologist; professor in the University of Chicago.
CHITTENDEN, FRANK H. (1858—). American entomologist; U. S. Department of Agriculture.
CHUN, CARL (1852–1914). German zoologist; professor in Leipzig.
CIENKOWSKY, LEON (b. 1822). Russian botanist and microscopist; professor in Charkow.
CLAPARÈDE, JEAN (1832–1871). Swiss zoologist; professor in Geneva.
CLARK, AUSTIN H. (1880—). American zoologist; U. S. National Museum.
CLARK, H. JAMES (1826–1873). American zoologist; professor in the Massachusetts Agricultural College in Amherst.
CLARK, HUBERT LYMAN (1870—). American zoologist; Museum of Comparative Zoology, Cambridge, Mass.
CLAUS, CARL (1835–1899). German zoologist; professor in Vienna.
CLERCK, CARL (b. 1757). Swedish entomologist and painter.
CLOQUET, JULES (1790–1843). French physician and naturalist; professor in Paris.
COBBOLD, THOMAS SPENCER (1828–1886). English helminthologist and naturalist; professor in the Royal Veterinary College, London.

Cockerell, T. D. A. (1866—). English-American zoologist; professor in University of Colorado.
Coe, Wesley R. (1869—). American zoologist; professor in Yale.
Cohn, Ferdinand (1828–1898). German botanist and microscopist; professor in Breslau.
Comstock, John Henry (1849—). American entomologist and arachnologist; professor in Cornell.
Conklin, Edwin G. (1863—). American zoologist; professor in Princeton.
Conn, Herbert W. (1859—). American zoologist and bacteriologist; professor in Wesleyan.
Conrad, Timothy A. (1803–1877). American conchologist and naturalist resident in Philadelphia.
Cook, Melville T. (1868—). American botanist; Delaware Agricultural Experiment Station.
Cooke, A. H. English clergyman and conchologist; headmaster of Aldenham School, Herts.
Cooper, J. G. American conchologist; latter half of the last century.
Cope, Edward D. (1840–1897). American zoologist and paleontologist; professor in the University of Pennsylvania.
Costa, Achille (d. 1898). Italian zoologist; professor in Naples.
Coues, Elliott (1842–1899). American ornithologist and army surgeon.
Councilman, William T. (1854—). Professor of pathology in Harvard.
Couthouy, Joseph P. (1808–1864). American conchologist; took part in the Wilkes Expedition.
Cowles, R. P. (1872—). American zoologist; university of the Philippines, Manila.
Crandall, O. A. American conchologist resident in Sedalia, Mo.
Crawley, Howard (1869—). American zoologist and protozoologist; Department of Agriculture, Washington.
Creplin, Friedrich. German parasitologist; first half of last century.
Crosby, Cyrus R. (1879—). American entomologist; professor in Cornell.
Cunningham, Daniel J. (1850–1909). Scotch physician and naturalist; professor in Dublin and Edinburgh.
Curtice, Cooper K. American parasitologist and veterinary; Department of Agriculture; latter part of last century.
Curtis, Winterton C. (1875—). American zoologist; professor in the University of Missouri.
Cushman, Joseph A. American zoologist; Boston Society of Natural History.
Cuvier, Georges, Baron de (1769–1832). French zoologist, paleontologist and comparative anatomist; professor in Paris.
Czerniavsky, Alexander von (1850—). Russian zoologist.

Da Costa, Emanuel. English conchologist; latter part of the 18th century.
Daday, Eugene. Hungarian zoologist; professor in Budapest.
Dall, William H. (1845—). American zoologist and conchologist; Smithsonian Institution, Washington.
Dalyell, John G. (1775–1851). Scotch naturalist and antiquary.
Dana, James Dwight (1813–1895). American geologist and zoologist; professor in Yale.
Danielssen, Cornelius. Norwegian zoologist; director of the Museum in Bergen.
Darwin, Charles (1809–1882). English naturalist and evolutionary philosopher.
Daudin, Francois (1774–1804). French zoologist.
Davenport, Charles B. (1866—). American zoologist; director of the Station for Experimental Evolution of the Carnegie Institution of Washington, the Eugenic Record Office and the Biological Laboratory, all at Cold Spring Harbor, L. I.
Davidoff, Michael. Russian zoologist; director of the Marine Laboratory in Villefranche, France.
Davidson, Thomas (1817–1885). Scotch paleontologist and zoologist.
Dean, Bashford (1867—). American zoologist; professor in Columbia.
Defrance, M. (1758–1850). French zoologist.
De Geer, Karl (1720–1778). Swedish zoologist.
DeKay, James E. (1782–1851). American naturalist and physician in Oyster Bay, L. I.

Delage, Marie-Yves (1854—). French zoologist; professor in Paris.
Delaroche, François (b. 1780). French icthyologist.
Delle Chiaje, Stefano (d. 1859). Italian zoologist and helminthologist; professor in Naples.
Deshayes, Girard (b. 1795). French conchologist; professor in Paris.
Desor, Edouard (1811–1882). German-Swiss geologist and naturalist; he accompanied Agassiz to America in 1846 but returned to Switzerland.
Diesing, Karl (1800–1867). Austrian zoologist and helminthologist resident in Vienna.
Dillwyn, Louis W. (1778–1855). English naturalist.
Dobie, M. W. English microscopist; middle of last century.
Döderlein, Ludwig (1855—). German zoologist; professor in Strassburg.
Dodge, Charles W. (1863—). American biologist; professor in Rochester University.
Doflein, Franz. German zoologist and protozoologist; professor in Freiburg.
Donovan, Edward (d. 1837). English naturalist and painter.
Doyère, Louis (b. 1811). French naturalist; professor in Versailles.
Draparnaud, Jacques (1772–1805). French conchologist; professor in Montpellier.
Drasche, Richard von. Austrian zoologist resident in Vienna.
Drew, Gilman A. (1868—). American zoologist; assistant director of the Marine Biological Laboratory, Woods Hole, Mass.
Düben, Gustav von. Swedish physician and zoologist; middle of last century.
Dubini, Angelo. Italian parasitologist and physician in Milan; first half of last century.
Duerden, J. E. English zoologist; professor in Rhodes University College, Grahamstown.
Dufour Léon (1782–1865). French entomologist and physician in St. Sever.
Dugès, Antoine (1798–1838). French zoologist and physician; professor in Montpellier.
Dujardin, Felix (1801–1860). French zoologist; professor in Paris.
Duméril, Andre (1774–1860). French physician and naturalist; professor in Paris.
Dumortier, Barth. Charles (1797–1878). French zoologist and botanist.
Dutton, J. Everett. English parasitologist and physician in the School of Tropical Medicine, Liverpool.

Edmondson, Charles H. (1869—). American zoologist; professor in Washburn College.
Edwards, Charles L. (1863—). American zoologist resident in Los Angeles.
Ehlers, Ernst (1835—). German zoologist; professor in Göttingen.
Ehrenberg, Christian Gottfried (1795–1876). German zoologist; professor in Berlin.
Eisen, Gustav (1847—). Swedish-American zoologist resident in San Francisco.
Elliott, Stephen (1771–1830). American naturalist; professor in the South Carolina State Medical College, Charleston.
Ellis, John (1710–1776). English zoologist; a merchant who was interested in natural science.
Emerton, James H. (1847—). American zoologist and arachnologist resident in Boston, Mass.
Entz, Géza. Hungarian zoologist; professor in Budapest.
Ercolani, G. B. Italian zoologist and helminthologist.
Erichson, Wilhelm (1809–1848). German zoologist; professor in Berlin.
Eschscholtz, Johann Friedrich (1793–1831). Russian zoologist and physician; professor in Dorpat.
Esper, Eugen (1742–1810). German zoologist; professor in Erlangen.
Eysenhardt, C. G. German zoologist and parasitologist; first half of last century.

Fabricius, Johann Christian (1745–1808). Danish zoologist; professor in Kiel.
Farre, Arthur (1811–1887). English physician and microscopist.
Faxon, Walter (1848—). American zoologist; Museum of Comparative Zoology, Cambridge, Mass.
Feletti, Raimondo. Italian physician and parasitologist; professor in Catania.
Férussac, Jean de (1786–1836). French conchologist and army officer.

Fewkes, J. Walter (1850—). American zoologist and ethnologist; Smithsonian Institution, Washington.
Fischer, Heinrich (1817–1886). German zoologist and mineralogist; professor in Freiburg.
Fischer, Paul (1835–1893). French conchologist and zoologist.
Fischöder, Franz (1865—). German veterinary and parasitologist; in Königsberg and Bromberg.
Fisher, Walter K. (1878—) American zoologist; professor in Leland Stanford.
Fitzinger, Leopold (1802–1884). Austrian zoologist resident in Vienna.
Fleming, John (1785–1857). Scotch zoologist; professor in Edinburgh.
Focke, Gustav (1810–1877). German naturalist and physician in Bremen.
Fol, Herman (1845–1892). Swiss zoologist; professor in Geneva.
Forbes, Edward (1815–1854). Scotch zoologist; professor in Edinburgh.
Forbes, Stephen A. (1844—). American zoologist; professor in the University of Illinois.
Forskal, Peter (1736–1768). Swedish naturalist and traveller.
Fraipont, Julien. Belgian zoologist and parasitologist; University of Liège.
Frantzius, Alexander. German microscopist; middle of last century.
Fraser, C. McLean. American zoologist; Biological Station, Nanaimo, B. C., Canada.
Fréminville, Christophe de (b. 1787). French zoologist and marine officer.
Fresenius, Georg (1806–1866). German microscopist.
Froelich, Johannes (d. 1841). German physician and entomologist.
Fromentel, Louis de (b. 1824). French physician and naturalist.
Fuessli, Johann (1743–1786). Swiss naturalist and entomologist; in Zurich.
Fürst, Camillo (1852—). Austrian physician in Vienna.

Gabb, William M. (1839–1878). American paleontologist.
Gaertner, Joseph (1732–1791). German naturalist; professor in Tübingen and Petrograd.
Gaimard, Paul (1790–1858). French zoologist; together with Quoy he made voyages to the South Seas in 1817 and 1826.
Galloway, Thomas W. (1866—). American zoologist; professor in Beloit College.
Garden, Alexander (1730–1791). American naturalist and physician in Charleston, S. C.
Garman, Harrison (1858—). American biologist; state entomologist of Kentucky.
Garrison, Philip E. American parasitologist; Marine Hospital Service, Washington.
Gegenbaur, Karl (1826–1903). German anatomist and zoologist; professor in Heidelberg.
Geoffroy-Saint-Hilaire, Étienne (1772-1844). French zoologist; professor in Paris; was in Egypt with Napoleon.
Gerlach, Andreas (1811-1877). German veterinary and parasitologist; professor in Berlin.
Gerould, John H. (1868—). American zoologist; professor in Dartmouth.
Gerstecker, Adolf (b. 1828). German zoologist; professor in Greifswald.
Gervais, Paul (1816–1879). French zoologist and paleontologist; professor in Paris.
Giard, Alfred (1846—). French zoologist; professor in Paris.
Gibbes, Robert W. (1809–1866). American naturalist and physician in Charleston, S. C.
Giesbrecht, Wilhelm. German zoologist; professor in the Zoological Station, Naples.
Gilbert, Augustin. French physician and professor in Paris.
Gill, Theodore N. (1837—). American zoologist; professor in George Washington University, Washington, D. C.
Girard, Charles (1822–1895). French-American zoologist; Smithsonian Institution.
Gmelin, Johann Friedrich (1748–1804). German naturalist; professor in Göttingen; edited the 13th edition of Linnaeus' Systema Naturae.
Godman, John D. (1794–1830). American naturalist and physician in Philadelphia.
Goeze, Johann (1748–1804). German parasitologist and pastor in Quedlinburg.
Goldfuss, Georg (1782–1848). German zoologist; professor in Bonn.

GOODE, GEORGE BROWN (1851–1896). American zoologist and ichthyologist; director of the U. S. National Museum.
GOSSE, PHILLIP HENRY (1810–1888). English zoologist and naturalist.
GOTO, SEITARO (1867—). Japanese zoologist; professor in Tokyo.
GOULD, AUGUSTUS A. (1805–1866). American zoologist and physician in Boston.
GRAFF, LUDWIG VON (1851—). Austrian zoologist; professor in Graz.
GRANT, ROBERT E. (1793–1874). English physician and zoologist; professor in London.
GRASSI, GIOVANNI BATTISTA. Italian zoologist and parasitologist; professor in Rome.
GRAVE, CASWELL (1870—). American zoologist; professor in Johns Hopkins.
GRAY, JOHN EDWARD (1800–1875). English naturalist; keeper of the zoological collections of the British Museum.
GREEF, RICHARD (b. 1829). German zoologist; professor in Marburg.
GRIFFIN, LAWRENCE E. (1874—). American zoologist; professor in Philippine Medical School, Manila.
GRIFFITH, EDWARD. English conchologist; first half of last century.
GRUBE, ADOLF (1812–1880). German zoologist; professor in Breslau.
GRUBER, AUGUST. German protozoologist; professor in Freiburg.
GRUBY, DAVID (1810–1898). French microscopist; professor in Paris.
GUERNE, JULES DE. French zoologist resident in Paris.
GUILDING, LANSDOWNE. English zoologist and naturalist; first half of last century.
GUNNERUS, JOHAN (1718–1773). Norwegian zoologist.
GURLEY, R. R. American physician and protozoologist; assistant in Fish Commission.

HAECKEL, ERNST (1834—). German zoologist; professor in Jena.
HAGEN, HERMANN (1817–1893). German-American entomologist; professor in Harvard.
HALDEMAN, SAMUEL S. (1812–1880). American naturalist; professor in the University of Pennsylvania.
HALL, MAURICE C. (1881—). American zoologist; Department of Agriculture, Washington.
HAMANN, OTTO (1857—). German zoologist; professor in Berlin.
HANCOCK, ALBANY (1806–1873). English zoologist and manufacturer.
HANLEY, SYLVANUS. English conchologist; middle of last century.
HANSEN, HANS J. Danish entomologist resident in Copenhagen.
HARGER, OSCAR (1843–1887). American zoologist; assistant in the Yale Museum.
HARGITT, CHARLES W. (1852—). American zoologist; professor in Syracuse University.
HARGITT, GEORGE T. (1881—). American zoologist; professor in Syracuse University; son of Charles W.
HARLAN, RICHARD (1796–1843). American naturalist and physician in Philadelphia.
HARRING, HARRY K. American zoologist; U. S. Bureau of Standards, Washington.
HARRIS, J. ARTHUR (1880—). American botanist and zoologist; Station for Experimental Evolution, Cold Spring Harbor, N. Y.
HARRIS, THADDEUS W. (1795–1856). American entomologist and physician in Boston.
HARTMAN, WILLIAM D. (1817–1899). American conchologist and physician in West Chester, Pa.
HARTMEYER, ROBERT. German zoologist; Zoological Museum, Berlin.
HARVEY, F. L. (d. 1900). American naturalist; professor in the University of Maine.
HASSALL, ALBERT (1862—). American parasitologist; Bureau of Animal Industry, Washington.
HATSCHEK, BERTHOLD (1854—). Austrian zoologist; professor in Vienna.
HAY, WILLIAM P. (1872—). American zoologist; professor in Washington, D. C.
HEIDER, KARL (1856—). Austrian zoologist; professor in Innsbruck.
HELLER, ARNOLD (1840—). German anatomist and parasitologist; professor in Kiel.
HEMPEL, A. American microscopist.
HENLE, FRIEDRICH (1809–1885). German physician and naturalist; professor in Göttingen.
HENRY, JOSEPH (1797–1878). American physicist; first secretary of the Smithsonian Institution.
HENTZ, NICHOLAS M. (1797–1856). German-American naturalist and educator.
HERDMAN, WILLIAM A. (1858—). Scotch zoologist; professor in Liverpool.

Hering, Edouard (b. 1834). German zoologist; professor in Prague.
Hermann, Jean (1738–1800). French physician and naturalist; professor in Strassburg.
Hérouard Edgard. French zoologist; professor in Paris.
Herrick, Clarence L. (1858–1904). American zoologist and naturalist; president of the University of New Mexico.
Herrick, Francis H. (1858—). American zoologist; professor in Western Reserve University.
Hertwig, Richard (1850—). German zoologist; professor in Munich.
Hesse, C. E. Belgian helminthologist; middle of last century.
Heyden, Lucas von. German zoologist and entomologist; professor in Frankfort.
Hincks, Thomas (1818–1899). English zoologist and clergyman in Leeds.
Hinds, Richard B. English navy surgeon and naturalist.
Holmes, Samuel J. (1868—). American zoologist; professor in the University of California.
Hubrecht, A. A. W. (1853–1914). Dutch zoologist; professor in Utrecht.
Hudson, Charles T. (1828–1903). English naturalist and teacher in Clifton.
Humbert, Alois. Swiss naturalist; middle of last century.
Humboldt, Alexander von (1769–1859). German traveller and naturalist.
Humphrey, George. English conchologist; latter part of eighteenth century.
Huxley, Thomas Henry (1825–1895). English zoologist and naturalist; professor in London.
Hyatt, Alpheus (1838–1902). American zoologist and paleontologist; Boston Society of Natural History.
Ihering, Hermann von (1850—). German-Brazilian zoologist; director of the Museum, Sao Paulo.

Illiger, Johannes (1775–1815). German zoologist; director of the Zoological Garden in Berlin.

Jackson, Robert T. (1861—). American paleontologist; professor in Harvard.
Jäger, H. German physician; professor in Königsberg.
Jägerskiold, Leonard von. Swedish zoologist and parasitologist; the Zoological Museum, Gothenburg.
Janet, Charles. French zoologist and engineer in Beauvais.
Jeffreys, John G. (1809–1885). English conchologist.
Jennings, Herbert S. (1868—). American zoologist; professor in Johns Hopkins.
Johansson, Ludwig. Swedish zoologist; in the University of Gothenburg.
Johnson, Herbert P. (1864—). American zoologist and protozoologist; professor in St. Louis.
Johnson, James R. Scotch physician in Edinburgh.
Johnston, George (1797–1855). Scotch naturalist and physician in Berwick on Tweed.
Jordan, David Starr (1851—). American ichthyologist and naturalist; Chancellor of Leland Stanford.
Juday, Chancey. American zoologist; lecturer in the University of Wisconsin.
Jurine, Louis (1751–1819). Swiss physician and zoologist; professor in Geneva.

Kalm, Peter (1715–1790). Swedish naturalist and pupil of Linnæus; travelled in America.
Keep, Josiah (1849–1913). American conchologist; professor in Mills College, California.
Keferstein, W. (1833–1870). German zoologist; professor in Göttingen.
Kellicott, David S. (1842–1898). American microscopist and zoologist; professor in Ohio State University.
Kellogg, James L. (1866—). American zoologist; professor in Williams.
Kellogg, Vernon L. (1867—). American entomologist and zoologist; professor in Leland Stanford.
Kent, W. Saville. English protozoologist and ichthyologist; formerly in the British Museum.
Kerbert, C. Dutch zoologist and parasitologist resident in Amsterdam.
Kessler, Karl (d. 1884). Russian zoologist; professor in Petrograd.
Keyserling, Alexander von (1815–1891). Russian naturalist and traveller.

KILBOURNE, EDWIN D. American army surgeon.
KING, WILLIAM (1809–1886). English geologist and naturalist; professor in Queens College, Galloway.
KINGSLEY, JOHN STERLING (1854—). American zoologist; professor in the University of Illinois.
KLEBS, GEORG. German botanist and microscopist; professor in Heidelberg.
KLEIN, JAKOB THEODOR (1685–1759). German zoologist; an opponent of Linnæus.
KOCH, CARL LUDWIG (1806–1888). German zoologist and arachnologist.
KOFOID, CHARLES A. (1865—). American zoologist; professor in the University of California.
KÖLLIKER, ALBERT VON (1817–1905). German anatomist and zoologist; professor in Würzburg.
KÖNIKE, FERDINAND. German zoologist resident in Bremen.
KOREN, J. Norwegian zoologist; custos in the Museum in Bergen.
KORSCHELT, EUGEN (1858—). German zoologist; professor in Marburg.
KOWALEVSKY, ALEXANDER (1840–1901). Russian zoologist; professor in Petrograd.
KRAEPELIN, KARL. German zoologist; director of the National History Museum, Hamburg.
KROHN, AUGUST. German zoologist; first half of last century.
KRÖYER, HENRIK (b. 1799). Danish naturalist resident in Copenhagen.
KÜCHENMEISTER, GOTTLOB (1821–1890). German parasitologist and physician in Zittau.
KURTZ, JOHN D. American conchologist and marine officer; middle of the last century.

LABBÉ, ALPHONSE. French protozoologist; School of Medicine in Nantes.
LACAZE-DUTHIERS, HENRI DE (1821–1901). French zoologist; professor in Paris.
LACHMANN, JOHANNES (1832–1860). German zoologist.
LAMARCK, JEAN, CHEVALIER DE (1744–1829). French zoologist, botanist, and evolutionary philosopher.
LAMBE, LAWRENCE M. (1863—). Canadian zoologist and paleontologist; Geological Survey of Canada.
LAMOUROUX, JEAN (1779–1825). French zoologist; professor in Paris.
LANDACRE, FRANCIS L. (1867—). American zoologist; professor in Ohio State University.
LANDOIS, HERMANN (b. 1835). German zoologist; professor in Münster.
LANG, ARNOLD (1855–1914). Swiss zoologist; professor in Zurich.
LANKESTER, E. RAY (1847—). English zoologist; director of the department of Natural History in the British Museum until 1907.
LATREILLE, PIERRE (1762–1833). French zoologist and entomologist; professor in Paris.
LAVERAN, ALPHONSE (1845—). French physician and microscopist; Pasteur Institute, Paris.
LEA, ISAAC (1792–1886). American conchologist and publisher in Philadelphia.
LEACH, WILLIAM E. (1790–1836). English zoologist; a curator in the British Museum.
LECLERC, M. French microscopist; first part of last century.
LE CONTE, JOHN EATON (1784–1860). American naturalist and army engineer; a brother of Lewis.
LE CONTE, JOHN LAWRENCE (1825–1883). American entomologist and a physician in Philadelphia; a son of John E.
LE CONTE, JOSEPH (1823–1901). American geologist; professor in the University of California; a son of Lewis.
LE CONTE, LEWIS (1782–1838). American naturalist and physician; a brother of John E.
LEDERMÜLLER, MARTIN (1719–1769). German physician and naturalist.
LEEUWENHOEK, ANTON (1632–1723). Dutch naturalist; one of the first to use the microscope to study animals.
LEFEVRE, GEORGE (1869—). American zoologist; professor in the University of Missouri.
LÉGER, LOUIS. French protozoologist; professor in Grenoble.
LEHMANN, RUDOLF. German conchologist and physician in Stettin; latter part of last century.

LEIDY, JOSEPH (1823–1891). American anatomist, zoologist, and paleontologist; professor in the University of Pennsylvania.
LENDENFELD, ROBERT VON (1858–1913). Austrian zoologist and naturalist; professor in Prague.
LESKE, NATHANAEL (1751–1786). German zoologist; professor in Marburg.
LESSER, FRIEDRICH (1692–1754). German naturalist and theologian.
LESSON, RÉNÉ (1794–1849). French naturalist and traveller; professor in Rochfort
LESUEUR, CHARLES ALEXANDER (1778–1857). French zoologist; lived in Philadelphia from 1817 to 1825.
LEUCKART, FRIEDRICH SIGISMUND (1794–1843). German zoologist; professor in Freiburg.
LEUCKART, RUDOLF (1822–1898). German zoologist and helminthologist; professor in Leipzig; nephew of Friedrich.
LEUNIS, JOHANNES (1802–1873). German naturalist; professor in Hildesheim.
LEVINSEN, MARIUS. Danish zoologist; docent in Copenhagen.
LEYDIG, FRANZ (b. 1821). German zoologist; professor in Bonn.
LICHTENSTEIN, MARTIN (1780–1857). German zoologist; professor in Berlin.
LIEVIN, SAMUEL. Russian-German naturalist and physician in Dantzig.
LILLJEBORG, WILHELM. Swedish zoologist; professor in Upsala; latter half of last century.
LINCK, JOHANNES (1674–1734). German zoologist and physician; professor in Leipzig.
LINDEMANN, KARL. Russian zoologist in Moscow; in middle of last century.
LINNAEUS, CAROLUS (1707–1778). Swedish naturalist; professor in Upsala.
LINSTOW, OTTO VON (1842—). German helminthologist and physician in Göttingen.
LINTON, EDWIN (1855—). American parasitologist; professor in Washington and Jefferson College.
LISTER, MARTIN (1638–1712). English physician and naturalist.
LJUNGMAN, AXEL. Swedish zoologist resident in Lilldal.
LOOSS, ARTHUR (1861—). German zoologist and helminthologist; professor in the Medical School, Cairo, and in Leipzig.
LÖSCH, F. Russian physician in Petrograd; latter part of last century.
LOVÉN, SVEN (1809–1895). Swedish zoologist; professor in Stockholm.
LUCAS, HIPPOLYTE (1815–1885). French entomologist and arachnologist.
LUBBOCK, JOHN, LORD AVEBURY (1834–1913). English naturalist and banker in London.
LUDWIG, HUBERT (1852–1914). German zoologist; professor in Bonn.
LÜHE, MAX (1870—). German zoologist; professor in Königsberg.
LÜTKEN, CHRISTIAN. Danish zoologist; professor in Copenhagen.
LYMAN, RUFUS A. American physiologist; professor in the University of Nebraska
LYMAN, THEODORE (1833–1897). American zoologist; Museum of Comparative Zoology, Cambridge, Mass.

MACBRIDE, ERNEST W. (1866—). English zoologist; professor in London.
MACCALLUM, WILLIAM G. (1874—). American pathologist and helminthologist; professor in Columbia.
MCCLENDON, JESSE F. (1880—). American zoologist; professor in the University of Minnesota.
MCCOOK, HENRY C. (1837–1911). American zoologist and preacher in Philadelphia
MCCRADY, JAMES (1831–1881). American zoologist; professor in the College of Charleston, S. C.
MCMURRICH, J. PLAYFAIR (1859—). American anatomist and zoologist; professor in Toronto.
MCNEILL, J. A. American naturalist and collector in Binghamton, N. Y.
MAGALHAES, PEDRO DE. Brazilian zoologist and helminthologist; professor in Rio Janeiro.
MALMGREN, A. J. (b. 1834). Finnish zoologist; professor in Helsingfors.
MANSON, SIR PATRICK (1844—). English physician and parasitologist; London School of Tropical Medicine.
MARCHIAFAVA, ETTORE. Italian physician; professor of pathology in Rome.
MARK, EDWARD L. (1849—). American zoologist; professor in Harvard.
MARSH, C. DWIGHT (1855—). American zoologist and botanist; Department of Agriculture, Washington.

MARSHALL, RUTH (1869—). American zoologist; head of Department of Biology, Rockford, Wis.

MARSHALL, WILLIAM S. (1866—). American zoologist; professor in the University of Wisconsin.

MARTYN, THOMAS. English conchologist and naturalist; last half of 18th century.

MARX, GEORGE. German-American arachnologist; U. S. National Museum.

MAST, SAMUEL O. (1871—). American zoologist; professor in Johns Hopkins.

MAUPAS, E. French protozoologist resident in Algiers.

MAYER, ALFRED G. (1868—). American zoologist; director of the Department of Marine Biology of the Carnegie Institution of Washington.

MEAD, ALBERT D. (1869—). American zoologist; professor in Brown.

MEINERT, F. Danish entomologist; the Zoological Museum in Copenhagen.

MENGE, A. (1808–1880). German arachnologist and zoologist.

MENKE, CARL THEODOR (1791–1861). German conchologist.

MENSCH, P. CALVIN (1864–1901). American zoologist; professor in Ursinus College.

MERESHKOWSKI, C. VON. Russian microscopist; latter half of last century.

MERTENS, CHARLES DE (1737–1788). Belgian physician and naturalist.

METCALF, MAYNARD M. (1868—). American zoologist resident in Oberlin, Ohio.

METSCHNIKOFF, ELIAS (1845—). Russian zoologist and bacteriologist; the Pasteur Institute, Paris.

MEYER, CHRISTIAN VON (1801–1869). German paleontologist.

MICHAEL, ALBERT D. (1836—). English arachnologist and microscopist; solicitor in London.

MICHAEL, ELLIS L. (1881—). American zoologist; the Marine Biological Station, San Diego.

MICHAELSON, WILHELM. German zoologist; the Natural History Museum in Hamburg.

MIDDENDORFF, ALEXANDER VON (b. 1815). Russian zoologist.

MIERS, EDWARD J. English zoologist; the British Museum.

MIGHELS, J. W. American conchologist and physician.

MILLER, J. S. English zoologist; in first half of last century.

MILNE-EDWARDS, HENRI (1800-1885). French zoologist; professor in Paris.

MINCHIN, E. A. (1866–1915). English zoologist; professor in London.

MITZMAIN, MAURICE B. (1882—). American entomologist and parasitologist; Bureau of Science, Manila.

MITCHELL, JOHN (d. 1768). American botanist and naturalist; he lived in Virginia.

MÖBIUS, KARL (1825–1909). German zoologist; professor in Kial.

MÖRCH, OTTO (1828–1878). Danish conchologist; the Museum in Copenhagen.

MOLL, H. P. (1810–1845). Danish zoologist.

MONTAGU, GEORGE (1751–1815). English conchologist and naturalist; captain in the English army during the American Revolution.

MONTFORT, DENIS DE (d. 1820). French conchologist.

MONTGOMERY, THOMAS H. (1873–1912). American zoologist; professor in University of Pennsylvania.

MONTICELLI, FRANCESCO S. Italian zoologist and helminthologist; professor in Naples.

MOORE, ANNE (1872—). American biologist; teacher in Normal School, San Diego, California.

MOORE, HENRY F. (1867—). American zoologist; the U. S. Bureau of Fisheries; brother of J. Percy.

MOORE, J. PERCY (1869—). American zoologist; professor in the University of Pennsylvania.

MORGAN, THOMAS H. (1866—). American zoologist; professor in Columbia.

MORSE, EDWARD S. (1838—). American zoologist and archæologist; director of the Peabody Academy of Sciences at Salem, Mass.

MOSELEY, HENRY N. (1844–1891). English zoologist; on the Challenger Expedition; a professor in Oxford.

MÜHLFELDT, MEGERLE VON. Austrian conchologist; first half of last century.

MÜLLER, FRITZ (1821–1897). German zoologist and teacher who in 1852 migrated to Brazil.

MÜLLER, JOHANNES (1801–1858). German anatomist, physiologist and naturalist; professor in Berlin.

MÜLLER, OTTO FRIEDRICH (1730–1784). Danish zoologist.

NALEPA, ALFRED. Austrian microscopist; gymnasium professor in Vienna.
NARDO, GIOVANNI (1802–1877). Italian parasitologist.
NELSON, JAMES A. (1875—). American zoologist; Department of Agriculture, Washington.
NEWPORT, GEORGE (1803–1854). English entomologist and zoologist.
NICKERSON, WINFIELD S. (1864—). American zoologist and physician in Davenport, North Dakota.
NICOLET, HERCULE. French entomologist; the middle of the last century.
NITZSCH, CHRISTIAN LUDWIG (1782–1837). German zoologist; professor in Halle.
NITZSCHE, HEINRICH (1845—). German zoologist; professor in the Royal Saxon Forest Academy in Tharand.
NORDMANN, ALEXANDER VON (1803–1866). Finnish zoologist; professor in Helsingfors.
NORDQUIST, OSCAR. Finnish zoologist.
NORMAN, ALFRED M. (1831—). English zoologist and clergyman.
NUTTALL, GEORGE H. F. (1862—). English physician and parasitologist; professor in Cambridge, England.
NUTTING, CHARLES C. (1858—). American zoologist; professor in Iowa State University.

ODHNER, TEODOR. Swedish zoologist; docent in Upsala.
ODIER, LOUIS (1748–1817). Swiss physician; professor in Geneva.
OERSTED, ANDREAS (1816–1873). Danish botanist and naturalist; professor in Copenhagen.
OKEN, LORENZ (1779–1851). German zoologist and natural philosopher; professor in Zürich.
OLFERS, IGNATZ FR. VON. German conchologist and naturalist resident in Berlin; first half of last century.
D'ORBIGNY, ALCIDE (1802–1857). French paleontologist and zoologist, and traveler in South America.
ORTMANN, ARNOLD (1863—). German-American zoologist; professor in Pittsburg.
OSBORN, HENRY L. (1857—). American zoologist; professor in Hamline University.
OSBORN, HERBERT (1856—). American entomologist; professor in Ohio State University.
OSBURN, RAYMOND C. (1872—). American zoologist; professor in Connecticut College for Women, New London, Conn.
OUDEMANS, A. C. Dutch zoologist; director of the Zoological Gardens in the Hague.
OWEN, RICHARD (1803–1892). English comparative anatomist and paleontologist.

PACKARD, ALPHEUS S. (1839–1905). American zoologist and entomologist; professor in Brown.
PAGENSTECKER, HEINRICH (b. 1825). German zoologist; professor in Heidelberg.
PALLAS, PETER (1741–1811). German zoologist and naturalist who lived long in Russia.
PALMER, T. CHALKLEY (1860—). American naturalist and manufacturer in Philadelphia.
PARROTT, PERCIVAL J. (1874—). American entomologist; New York Experiment Station.
PARTSCH, PAUL (1791–1856). German conchologist.
PATTEN, WILLIAM (1861—). American zoologist; professor in Dartmouth.
PATTON, W. SCOTT. English protozoologist and physician in the King Institute of Preventative Medicine, India.
PAULMEIER, FREDERIC P. (1873–1906). American zoologist; State Museum, Albany, New York.
PEALE, CHARLES WILSON (1741–1827). American portrait painter resident in Philadelphia.
PEALE, REMBRANDT (1778–1860). American portrait painter and naturalist resident in Philadelphia and Baltimore; son of Charles Wilson Peale.
PEARL, RAYMOND (1867—). American zoologist; Maine Agricultural Experiment Station.
PEARSE, ARTHUR S. (1877—). American zoologist; instructor in the University of Michigan.
PECKHAM, ELIZABETH G. (1854—). American entomologist and arachnologist; wife of George W.

PECKHAM, GEORGE W. (1845–1914). American entomologist and arachnologist; teacher and librarian in Milwaukee.
PELSENEER, PAUL. Belgian zoologist; professor in Ghent.
PERKINS, HENRY F. (1877—). American zoologist; professor in the University of Vermont.
PÉRON, FRANÇOIS (1775–1810). French naturalist and soldier; went with Lesueur on his South Sea voyage in 1800–1804.
PERRIER, EDMOND (1844—). French zoologist; professor in Paris.
PERRY, GEORGE. English conchologist; first part of last century.
PERTY, MAXMILIAN (1804–1884). German naturalist; professor in Berne.
PETERS, WILHELM (1815–1883). German traveler and zoologist; professor in Berlin.
PEYSSONNEL, ANTOINE (b. 1694). French naturalist and physician in Marseilles.
PFEIFFER, LUDWIG (1842—). German conchologist and physician in Cassel.
PHILIPPI, RUDOLF (b. 1808). German zoologist and naturalist; traveler in South America.
PHIPPS, CONSTANTINE JOHN (1746–1892). English naval officer.
PIERSIG, RICHARD. German zoologist; teacher in Annenberg.
PILSBRY, HENRY A. (1862—). American conchologist; Academy of Natural Sciences, Philadelphia.
PLATE, LUDWIG (1862—). German zoologist; professor in Jena.
PLINY MAJOR, CAIUS (23-79). Roman writer on Natural History; killed at the eruption of Vesuvius which destroyed Pompeii.
PLUMMER, GEORGE A. American navy surgeon.
POCOCK, REGINALD I. (1863—). English zoologist; the Zoological Gardens, London.
POIRIER, J. French parasitologist; professor in Clermont-Ferrand.
POLI, GUISEPPE (1746–1825). Italian naturalist resident in Naples.
POTTS, EDWARD (1830–1912). American zoologist and microscopist resident in Media, Pa.
POUCHET, FÉLIX (1800–1872). French naturalist and physician in Rouen.
POURTALÈS, LOUIS DE (1823–1880). French-American zoologist who accompanied Agassiz to America; Director of the Museum of Comparative Zoology of Harvard College.
POWERS, JOSEPH H. (1866—). American zoologist; professor in the University of Nebraska.
PRATT, HENRY S. (1859—). American zoologist; professor in Haverford College.
PRÉVOST, ISAAC (1755–1819). Swiss naturalist; professor in Montauban.
PRICE, MARSHALL L. (1878—). American physician in Baltimore.
PRIME, TEMPLE. American conchologist resident in New York City.
PURKINJE, JOHANN (1787–1869). Bohemian physiologist; professor in Prague.
PUTNAM, J. DUNCAN (1855–1881). American zoologist resident in Davenport, Iowa.

QUATREFAGES, JEAN DE (1810–1892). French zoologist; professor in Paris.
QUENNERSTEDT, A. Swedish zoologist and protozoologist; middle of the last century.
QUOY, JEAN (1790–1869). French zoologist; together with Gaimard he made voyages to the South Sea in 1817 and 1826.

RACKETT, THOMAS (1757–1841). English naturalist and clergyman.
RAFINESQUE, CONSTANTINE (1784–1842). French-American naturalist and traveler resident in Lexington, Ky., and Philadelphia.
RAILLET, ALCIDE (1852—). French zoologist and physician; professor in Alfort.
RANG, ALEXANDER. French marine officer and zoologist.
RANSOM, BRAYTON H. (1879—). American parasitologist; chief of the zoological division of the Bureau of Animal Industry, Washington.
RATHBUN, MARY J. (1860—). American zoologist; U. S. National Museum.
RATHBUN, RICHARD (1852—). American zoologist; Smithsonian Institution.
RATHKE, MARTIN (1793–1860). German zoologist; professor in Königsberg.
RAY, JOHN (1628–1705). English naturalist and clergyman.
REESE, DAVID M. (1800–1861). American naturalist and physician in New York.
REEVE, LOVELL A. (1814–1865). English conchologist and merchant.
RENIER, STEFANO (1759–1830). Italian zoologist.
RETZIUS, ANDREAS JOANNES (1742–1821). Swedish naturalist and helminthologist; professor in Lund.
RICHARDSON, HARRIET. American zoologist; Smithsonian Institution.

Riehm, Johann (1739–1807). German agriculturist and naturalist.
Riley, Charles V. (1843–1895). American economic entomologist; U. S. National Museum, Washington.
Risser, Jonathan (1869—). American zoologist; professor in Washburn College.
Risso, J. A. (1777–1845). Italian naturalist; professor in Nice.
Ritter, William E. (1856—). American zoologist; professor in the University of California.
Ritter-Zahony, Rudolf von. German zoologist resident in Berlin.
Rivolta, Sebastiano (1832–1893). Italian parasitologist.
Robertson, Alice. American zoologist; professor in Wellesley.
Robin, Charles Phillipe (1821–1885). French zoologist and anatomist; professor in Paris.
Roederer, Johann (1726–1763). German physician; professor in Göttingen.
Rogers, Charles G. (1875—). American zoologist and physiologist; professor in Syracuse University.
Rondelet, Guillaume (1507–1556). French naturalist and physician.
Rousselet, Charles F. English microscopist and zoologist resident in London.
Roux, Jean. French naturalist and physician in Marseilles.
Rucker, Augusta (1873—). American zoologist; instructor in the University of Texas.
Rudolphi, Carl Asmund (1771–1832). Swedish zoologist and helminthologist; professor in Berlin.
Rüppell, Wilhelm (1794–1884). German zoologist and African explorer.
Ryder, John A. (1852–1895). American zoologist; professor in the University of Pennsylvania.

Sager, Abram (1811–1877). American zoologist resident in Ann Arbor, Mich.
Sars, Georg O. (1837—). Norwegian zoologist; professor in Christiania; son of Michael.
Sars, Michael (1805–1869). Norwegian zoologist; professor in Christiania.
Saussure, Nicholas de (1767–1845). Swiss naturalist and chemist.
Savigny, M. J. C. de (1778–1851). French zoologist; went with Napoleon to Egypt.
Say, Thomas (1787–1834). American zoologist; the Academy of Natural Sciences of Philadelphia.
Scapoli, Johann (1725–1788). Austrian naturalist; professor in Pavia.
Schacht, F. W. American zoologist; teacher in Chicago High School.
Schaeffer, Asa A. American zoologist; professor in the University of Tennessee.
Schaeffer, Jacob (1718–1790). German zoologist and botanist.
Schaudinn, Fritz (1871–1906). German zoologist and protozoologist; docent in Berlin.
Schick, Morris. American conchologist resident in Philadelphia.
Schlumberger, Charles (1859—). French paleontologist.
Schmeil, Otto (1860—). German zoologist and botanist resident in Heidelberg.
Schmidt, Oscar (1823–1886). German zoologist; professor in Strassburg.
Schneider, Aimé. French zoologist and protozoologist; professor in Poitiers.
Schneider, Anton (b. 1831). German zoologist; professor in Breslau.
Schrank, Franz von (1747–1835). German botanist and zoologist; director of the Botanical Garden in Munich.
Schultze, Max (1825–1874). German anatomist and naturalist; professor in Bonn.
Schultze, Sigismund (1798–1874). German anatomist and naturalist; professor in Greifswald.
Schulze, Franz Eilhard (1840—). German zoologist; professor in Berlin.
Schumacher, Christian (1757–1830). Danish naturalist; professor in Copenhagen.
Schweigger, August (1783–1821). German botanist; professor in Königsberg.
Scudder, Samuel H. (1837–1911). American entomologist resident in Cambridge, Massachusetts.
Sedgwick, Adam (1854–1913). English zoologist; professor in Cambridge.
Sedgwick, William T. (1855—). American biologist; professor in the Massachusetts Institute of Technology.
Selenka, Emil (1842—). German zoologist; professor in Erlangen.
Semper, Carl (1832–1893). German zoologist and traveler; professor in Würzburg.
Shaffer, Elmer (1892—). American zoologist; student in Haverford and Princeton.

HANTZ, HOMER L. American zoologist and botanist; Department of Agriculture, Washington.
HARP, BENJAMIN (1858–1914). American zoologist and traveler resident in Philadelphia.
HARPE, RICHARD W. (1869—). American zoologist; teacher in DeWitt Clinton High School, N. Y.
HAW, GEORGE (1751–1813). English zoologist and physician in London.
HAW, WALTER R. (1871—). American botanist and entomologist; professor in the University of the Philippines.
HIPLEY, ARTHUR E. (1861—). English zoologist; lecturer in Cambridge.
HULL, A. FRANKLIN. American zoologist; professor in the University of Michigan.
HUTTLEWORTH, ROBERT J. (1810–1874). English botanist and conchologist.
IEBOLD, CARL THEODOR ERNST VON (1804–1885). German zoologist; professor in Munich.
ILLIMAN, BENJAMIN (1779–1864). American scientist; professor in Yale.
ILLIMAN, WYLLIS A. American zoologist resident in Clarkson, N. Y.
IMON, EUGÈNE (1848—). French arachnologist resident in Paris.
IMPSON, CHARLES T. (1846—). American conchologist; U. S. National Museum.
IMROTH, HEINRICH (1851—). German zoologist; professor in Leipzig.
LABBER, MARTIN (1741-1835). Dutch naturalist.
LADEN, W. PERCY. English zoologist.
MALLWOOD, WILLIAM M. (1873—). American zoologist; professor in Syracuse University.
MITH, CLAUDE A. American physician in Atlanta, Georgia.
MITH, FRANK (1857—). American zoologist; professor in the University of Illinois.
MITH, HUGH M. (1865—). American ichthyologist; U. S. Commissioner of Fisheries.
MITH, SIDNEY I. (1843—). American zoologist; professor in Yale.
MITH, THEOBALD (1859—). American protozoologist and bacteriologist; Rockefeller Institute.
OLANDER, DANIEL (1736–1782). Swedish-English zoologist and botanist; a keeper of the British Museum.
OWERBY, GEORGE B. (1788–1834). English zoologist and conchologist.
OWERBY, GEORGE B. (1812–1884). English zoologist and conchologist; son of above.
PENGEL, JOHANN WILHELM (1852—). German zoologist; professor in Giessen.
PENGLER, LORENZ (b. 1720). German conchologist.
TAFFORD, JOSEPH (1867—). Canadian zoologist and parasitologist; lecturer in McGill University.
TARCOVICI, C. Italian veterinary and parasitologist.
TEBBING, THOMAS R. (1835—). English zoologist and clergyman in Tunbridge Wells.
TEEL, JOHN HENRY (d. 1891). English parasitologist and veterinary in Bombay Veterinary College.
TEENSTRUP, JOHANN JAPHETUS (1813–1897). Danish zoologist; professor in Copenhagen.
TEIN, FRIEDRICH (1818–1885). German zoologist; professor in Prague.
TERKI, VICTOR (1846—). Swiss-American zoologist and physician in New Philadelphia, Ohio.
TEVENS, NETTIE M. (1861–1913). American zoologist and cytologist; associate in Bryn Mawr.
TILES, CHARLES W. (1867—). American zoologist and parasitologist; head zoologist of the Hygienic Laboratory of the U. S. Marine Hospital Service.
TIMPSON, WILLIAM (1832–1872). American zoologist; curator of the Academy of Sciences in Chicago.
TOKES, ALFRED C. American microscopist and physician in Trenton, N. J.
TOLC, ANT. Bohemian zoologist; in the Technical High School in Prague.
TONE, GEORGE E. (1860—). American botanist; professor in Massachusetts Agricultural College, Amherst.
TORER, DAVID H. (b. 1804). American physician and naturalist in Boston.
TRAUS-DÜRKHEIM, HERCULES (1790–1865). French zoologist and comparative anatomist.
TRÖM, HANS. Norwegian naturalist and physician; first part of last century.
TUMMER, RUDOLF VON (1866—). Austrian zoologist; professor in Graz.

SUMNER, FRANCIS B. (1874—). American zoologist; Scripp's Institute for Biological Research, La Jolla, Cal.
SUNDEVALL, CARL (b. 1801). Swedish zoologist; professor in Lund.
SURFACE, FRANK M. (1882—). American biologist; Maine Agriculture Experiment Station, Orono.
SWAINSON, WILLIAM (1789–1855). English naturalist and traveler.

TAPPAN, BENJAMIN. American conchologist; middle of last century.
TASCHENBERG, ERNST (1818–1898). German zoologist and entomologist; professor in Halle.
TATEM, J. G. English microscopist and protozoologist.
TENNANT, DAVID H. (1873—). American zoologist; professor in Bryn Mawr.
THÉEL, JOHANN. Swedish zoologist.
THOMAS, ALGERNON P. W. English physician and parasitologist; professor in Auckland, N. Z.
THOMPSON, CAROLINE B. (1869—). American zoologist; professor in Wellesley.
THOMPSON, CHARLES WYVILLE (1830–1882). Scotch zoologist; professor in Edinburgh; sailed on the Challenger.
THOMPSON, D'ARCY W. (1860—). Scotch zoologist; professor in Dundee.
THOMPSON, JOHN V. (1779–1847). English zoologist and army surgeon.
THORELL, TAMERLAN. Swedish zoologist and arachnologist; middle of last century.
THORPE, V. G. English physician and microscopist; latter half of last century.
TIEDEMANN, FRIEDRICH (1781–1861). German zoologist; professor in Heidelberg.
TOPPE, OTTO. German zoologist; assistant in Rostock.
TORREY, HARRY B. (1873—). American zoologist; professor in Reed College, Portland, Oregon.
TOTTEN, JOSEPH G. American conchologist; middle of last century.
TREMBLEY, ABRAHAM (1700–1784). Swiss naturalist, and teacher in The Hague, Holland.
TROUESSART, EDOUARD LOUIS (1842—). French zoologist; professor in Paris.
TROSCHEL, FRANZ (1810–1882). German zoologist; professor in Bonn.
TRYON, GEORGE W. (1838–1888). American conchologist; Academy of Natural Sciences, Philadelphia.
TULLBERG, TYCHO. Swedish zoologist; professor in Upsala.
TURNER, C. H. American zoologist; teacher in Augusta, Georgia.
TURTON, WILLIAM (1762–1835). English conchologist and physician in Swansea.

D'UDEKEM, JULIUS. Belgian zoologist; middle of last century.

VALENTIN, GABRIEL (1810–1883). German physician; professor in Breslau and Berne.
VANATTA, E. G. American conchologist in the Academy of Natural Sciences, Philadelphia.
VAN NAME, WILLARD G. (1872—). American zoologist resident in New Haven.
VAUGHAN, T. WAYLAND (1870—). American paleontologist and geologist; the U. S. Geological Survey.
VEJDOVSKY, FR. (1849—). Bohemian zoologist; professor in Prague.
VERHOEFF, KARL WILHELM. German zoologist resident in Cannstatt.
VERRILL, ADDISON E. (1839—). American zoologist; professor in Yale.
VOGT, CARL (1817–1895). German-Swiss zoologist; professor in Geneva.
VOSMAER, G. C. J. Dutch zoologist; professor in Leyden.

WAGNER, FRANZ VON. Austrian zoologist; professor in Prague.
WALCKENAER, CHARLES (1771–1852). French arachnologist and zoologist; secretary of the Paris Academy of Sciences.
WALKER, BRYANT (1856—). American conchologist and lawyer in Detroit.
WALLICH, NATHANIEL (1786–1854). Danish-English botanist, naturalist and physician in India.
WALTER, HERBERT E. (1867—). American zoologist; professor in Brown.
WALTON, L. B. (1871—). American zoologist; professor in Kenyon College, Ohio.
WARD, HENRY B. (1865—). American zoologist and parasitologist; professor in the University of Illinois.
WECKEL, ADA L. American zoologist resident in Chicago.

WEBSTER, HARRISON E. American zoologist and president of Union College.
WEED, CLARENCE M. (1864—). American entomologist; instructor in State Normal School, Lowell, Mass.
WEINLAND, CHRISTOPHER (b. 1829). German physician and zoologist.
WELCH, WILLIAM HENRY (1850—). American physician and bacteriologist; professor in Johns Hopkins.
WERNER, CARL (d. 1863). German zoologist.
WESTRING, NIKLAS (1797–1882). Swedish arachnologist.
WESTWOOD, JOHN O. (1805–1893). English entomologist and naturalist.
WEYSSE, ARTHUR W. (1867—). American zoologist; professor in Boston University.
WHEELER, WILLIAM M. (1865—). American zoologist and entomologist; professor in Harvard.
WHIPPLE, GEORGE C. (1866—). American sanitary engineer in New York City.
WHITMAN, CHARLES O. (1842–1910). American zoologist; professor in the University of Chicago.
WHITNEY, DAVID D. (1878—). American zoologist; professor in Wesleyan.
WEIGMANN, AREND (1802–1841). German zoologist; professor in Berlin.
WILDER, HARRIS H. (1864—). American zoologist; professor in Smith College.
WILHELMI, JULIUS. German zoologist resident in Berlin.
WILLEMOES-SULM, RUDOLF VON (d. 1876). German zoologist; sailed on the Challenger Expedition; professor in Munich.
WILLEY, ARTHUR (1867—). English zoologist; professor in McGill University.
WILLIAMS, LEONARD W. (1875–1813). American zoologist and comparative anatomist; instructor in Harvard.
WILLIAMS, STEPHEN R. (1870—). American zoologist; professor in Miami University.
WILSON, ALEXANDER (1766–1813). Scotch-American ornithologist resident in Philadelphia.
WILSON, CHARLES B. (1861—). American zoologist; professor in State Normal School, Westfield, Mass.
WILSON, EDMUND B. (1856—). American zoologist; professor in Columbia.
WILSON, HENRY V. (1863—). American zoologist; professor in the University of North Carolina.
WOLCOTT, ROBERT H. (1868—). American zoologist; professor in the University of Nebraska.
WOLFF, EUGEN. German zoologist and entomologist; docent in Frankfort.
WOOD, HORATIO C. (1841—). American zoologist and physician; professor in the University of Pennsylvania.
WOODRUFF, LORANDE LOSS (1879—). American protozoologist and zoologist; professor in Yale.
WOODWORTH, WILLIAM MCM. (1864–1912). American zoologist; Museum of Comparative Anatomy, Cambridge, Mass.
WRIGHT, R. RAMSEY (1852—). Canadian zoologist; professor in Toronto.
WRIGHT, THOMAS (1809–1884). Scotch physician and naturalist.
WRIGHT, WILLIAM (1735–1819). English naturalist and physician in the West Indies and Edinburgh.
WRZESNIOWSKI, A. Polish zoologist and protozoologist; middle of last century.

YARRELL, WILLIAM (1784–1856). English zoologist and merchant in London.

ZADDACH, ERNST (1817–1881). German zoologist; professor in Königsberg.
ZEDER, J. G. H. German helminthologist and physician in Lichtenfels at the beginning of the last century.
ZELINKA, CARL. Austrian zoologist; professor in Czernowitz.
ZELLER, PHILLIP (1808–1883). German zoologist and entomologist.
ZENKER, FRIEDRICH VON (1815–1898). German anatomist and zoologist; professor in Erlangen.
ZSCHOKKE, FRIEDRICH. Swiss zoologist; professor in Basle.
ZÜRN, FRIEDRICH (1835–1900). German veterinary and parasitologist; professor in Leipzig.

GLOSSARY

Abdomen. The most posterior body-division in arthropods and in some other invertebrates.

Aboral. The side of the body opposite the mouth in a radiate animal.

Aciculum. A chitinous supporting rod in the parapodia of annelids.

Acontium. A vibratile thread-like organ charged with nettle cells in certain sea anemones.

Acraspedote medusa. A medusa without a velum. A scyphomedusan.

Acrocyst. A brood-chamber in certain campanularian hydroids.

Actinule. A larval form of certain hydroids.

Adaptive gills. Projections on certain opisthobranchs which function as gills, but are not ctenidia.

Adductor muscle. A muscle which draws an organ towards the axis of the body.

Algae. Very simple green plants.

Alimentary tract. The digestive canal, the organ which ingests, digests, and absorbs the food.

Alternation of generations. The alternate succession of sexual and asexual generations in a species of animals or plants.

Ambulacral feet. Tubular projections of the body wall with sucker discs at their ends in echinoderms.

Ambulacral groove. The elongated groove on the oral side of the rays of the starfish.

Ambulacral pores. Minute openings in the body-wall in the starfish and the sea-urchin.

Ampulla. A sac-like projection of the ambulacral foot in echinoderms.

Anal feelers. Paired posterior appendages which are sensory in function.

Analogous. Having a similar function.

Antenna. A segmented sensory appendage on the head.

Antennal scale. The exopodite of the second antenna in certain malacostracans.

Antennal sinus. An indentation in the shell near the antennae of certain ostracods.

Anterior. At or towards the front end of the body.

Anus. The posterior opening of the digestive canal.

Aorta. A large artery leading directly from the heart.

Aperture. The opening of a snail shell.

Apex. The tip of a snail shell.

Appendage. A projection from some part of the body.

Appendix. A short diverticulum usually of the intestine.

Archeocytes. Primitive cells in the mesoglea of sponges.

Aristotle's lantern. The dentary apparatus of the sea-urchin.

Artery. A blood vessel carrying blood away from the heart to the tissues.

Arthrobranch. A gill attached to the joint between the leg and the body in crustaceans.

Articulate. Composed of a series of homologous segments.

Asexual. Reproduction by division or budding and not through the agency of the sexes.

Atoke. The anterior, sexless part of certain annelids.

Auricle. A chamber of the heart which receives the blood from the veins.

Autozooid. A feeding zooid in the Pennatulacea.
Avicularium. A structure shaped like a bird's head attached to the zoœcium in Bryozoa.
Axial organ. A glandular organ in the axial sinus in echinoderms.
Axial sinus. An elongated sac alongside the stone canal in echinoderms.

Basals. Calcareous interradial plates in the crinoid body.
Bilateral symmetry. Having the right and the left sides alike.
Bivalve. A shell composed of two distinct and equivalent parts or valves.
Bladder worm. The larval stage of tapeworms.
Blastostyle. The reproductive polyp of a campanularian hydroid.
Body-cavity. An internal space in the body in which lie the viscera.
Body-wall. The outer portion of the body, which usually bounds the body-cavity towards the inside.
Brachial. Relating to the arms.
Branchial. Relating to the gills.
Branchial heart. A lateral heart in the squid which receives blood from one of the gills.
Branchiate. Bearing gills.
Branchiostegite. Paired lateral folds of the body-wall in crustaceans which protect the gills.
Brood-sac. A chamber in which the eggs develop in certain crustaceans.
Brown body. A round mass in certain bryozoans resulting from the disintegration of the soft parts of the body.
Bud. An outgrowth of the body of an animal which becomes a new individual.
Byssus. Cuticular threads secreted by the foot of many pelecypods and used to attach the shell.

Cœcum. A sac-like appendage of the digestive tract; a blind gut.
Calamistrum. A comb of stiff hairs on the fourth leg in certain spiders used by the animal to make a band of silk which stretches across the web.
Calcareous. Formed of carbonate of lime.
Callus. A thickening near the umbilicus in certain snail shells.
Calyx. The body of a crinoid.
Canal. A tubular prolongation of the lip of the aperture containing the siphon in many snail shells.
Carapace. The shell covering a portion or all of the cephalothorax in crustaceans.
Cardinal teeth. The hinge teeth beneath the umbo in a bivalve shell.
Carina. The median dorsal shell in barnacles.
Cartilage. The internal portion of the ligament in certain bivalve shells.
Cellulose. The woody cell-wall of plant cells and also of certain cells in the tunic of tunicates.
Central teeth. In the radula of mollusks the central row of teeth.
Centrodorsal. The basal portion of a non-sessile crinoid.
Cephalic gland. A tubular organ at the anterior end of nemerteans.
Cephalont. A sporozoon, when attached.
Cephalothorax. A body-division formed by the fusion of the head and the thorax in arthropods.
Cerata. Dorsal projections in opisthobranchs.
Ceratine. A horn-like substance forming the skeleton in certain corals.
Cercaria. A larval form of trematodes.
Cercus. A paired sensory projection at the posterior end in certain invertebrates.
Cerebral tube. A sense organ of sipunculids.
Chelate. Having forceps-like pincers.

Cheliped. The large grasping claw in many crustaceans.
Chitin. A hard and very resistant substance present in the cuticula of many arthropods.
Chlorophyll. The green coloring matter of plants.
Chromatophores. Colored pigment cells.
Cilia. The numerous vibratory projections on both the inner and the outer surfaces of certain animals.
Cirrus. A filamentous, sensory appendage of annelids; a protrusile copulatory organ of flatworms.
Clitellum. A thickened glandular region on oligochæts which secretes the cocoon.
Cloaca. A tubular or sac-like space which receives the discharge of various organs.
Cnidoblast. A stinging cell in Cnidaria which contains the nematocyst.
Cnidocil. A minute spine projecting from a nettle cell into the water.
Cocoon. A case containing one or more developing animals.
Cœlom. The body-cavity.
Cœnenchym. The soft parts of an alcyonarian colony.
Collar. The ventral edge of the mantle in gastropods and cephalopods; the part of the body of Balanoglossus between the proboscis and the trunk.
Collar cell. A flagellate cell with a high membrane around the base of the flagellum.
Colon. A division of the intestine.
Columella. The axis of a spiral snail shell.
Complementary male. A minute accessory male animal in certain barnacles.
Compound eye. An eye made up of a number of separate elements, or ommatidia, in arthropods.
Conjugation. The fusion of two protozoans and interchange of nuclear matter.
Connective tissue. A tissue whose principal function is to support and hold in place other tissues and organs.
Coxa. The proximal segment of an arthropod's leg, by which it articulates with the body.
Coxal plate. A plate in the ventral surface of Acarina.
Craspedote medusa. A medusa with a velum, a hydromedusan.
Cribellum. A plate with spinning tubes in front of the spinnerets in some spiders.
Cribriform organs. Parallel, vertical rows of thin calcareous plates in the margins of the arms of certain starfish.
Crop. A dilated portion of the œsophagus.
Ctenidium. The molluscan gill.
Cuticula. The outer layer of the integument of most invertebrates.
Cyst. A capsule containing an animal usually in a state of suspended animation; a capsule containing a foreign or inert body imbedded in some animal tissue.
Cysticercoid. A minute bladder worm in which the scolex completely fills the cyst.
Cysticercus. A bladder worm in which the cyst contains one or more scolices and a fluid.

Dart sac. A part of the genital tract of certain pulmonate snails.
Dentary apparatus. The five teeth and their supporting structure in the sea-urchin.
Desor's larva. A nemertean larval form.
Development. The series of changes in the early life of an animal by which it passes from the condition of a fertilized egg to that of the adult.

Dimorphism. The condition in which a species exists in two distinct forms, as, for instance, male and female.
Diœcious. Having the two sexes in two separate individuals.
Dissepiment. The partitions between the somites in annelids.
Distal. The position of a part of an organ away from the point of attachment —opposed to proximal.
Diverticulum. A sac-like projection of a tubular organ.
Dorsal. On or towards the back.
Dorsal lamina. A ciliated ridge in the mid-dorsal line of the pharynx in the ascidean.

Ectocyst. The zoœcium or outer wall of a bryozoan's body.
Ectoderm. The outermost layer of cells in the Cœlenterata.
Ectosarc. The outermost layer of non-granular protoplasm in protozoans.
Elytra. The imbricated scales on the back of certain annelids; the wing-covers of beetles.
Embryo. A young animal which is passing through its developmental stages, usually within the egg membranes or in the maternal uterus.
Encyst. The act of an animal in forming a cyst about itself.
Endopodite. The innermost of the two terminal branches of the typical crustacean leg.
Endostyle. A ciliated, glandular groove in the midventral line of the pharynx of tunicates and of Amphioxus.
Entoderm. The innermost layer of cells in the Cœlenterata.
Entosarc. The interior granular protoplasm in protozoans.
Ephippium. The shell in which the winter eggs of Cladocera are often contained.
Ephyra. A youthful stage in the growth of a scyphomedusan.
Epigynum. A plate over the genital orifice in the female spider.
Epiphragm. The disc of calcified slime with which a land pulmonate can close the opening of its shell.
Epipodium. A ridge along the side of the molluscan foot.
Epistome. A projection above the mouth in certain bryozoans.
Epitoke. The posterior sexual part of the body of certain annelids.
Erineum. A pathological plant-growth caused by certain mites.
Exopodite. The outermost of the two terminal branches of the typical crustacean leg.
Extensor muscle. A muscle that extends an organ.
Extremity. A paired lateral or ventral appendage of the body of an animal, used primarily for locomotion, although in many cases having secondarily some other function.
Exumbrella. The aboral side of a medusa.

Fertilization. The union of the spermatozoön and the ovum.
Flagellum. A vibratory thread-like projection of certain cells; the terminal portion of the antennae in crustaceans.
Flame cell. The terminal cell of an excretory tubule in the kidney of Plathelminthes.
Flexor muscles. A muscle that bends an organ.
Food vacuole. A globule of water containing food particles in protozoans.
Frontal appendage. A pair of extra appendages between the second antennae in certain Branchiopoda.
Frontal organ. Sensory organs near the front end of certain nemerteans.
Funiculus. A mesenteric strand connecting the stomach pouch with the body-wall in bryozoans.
Funnel. The siphon of a cephalopod
Furca. A pair of projections at the hinder end of the body of copepods.

Ganglion. An aggregation of nerve cells.
Gastrovascular space. The central cavity in Cnidaria and Ctenophora.
Gastrozooid. A feeding zooid of a siphonophore colony.
Gemmule. A capsule in fresh-water sponges containing archeocytes which live through the winter and in the spring form the starting point of a new sponge-colony.
Gastrula. A stage in the development of the embryo in which two cell layers are present, ectoderm and entoderm.
Gill. An organ for the breathing of air contained in the water.
Gill-filament. Ciliated vertical ridges on the surface of the gills of pelecypods.
Girdle. An integumental fold in chitons surrounding the shell.
Gizzard. A portion of the alimentary tract in certain animals with thickened muscular walls in which the food is chewed.
Glochidium. The larval form of Anodonta and Unio which lives a parasitic life in the skin of fishes.
Gnathopod. A grasping claw in amphipods.
Gonangium. The cuticular covering or gonotheca of the blastostyle in campanularian hydroids.
Gonosome. The medusoid stage of a hydromedusan.
Gonotheca. The cuticular outer covering of the blastostyle.
Gonozooid. The reproductive zooid of a siphonophore colony.

Hœmal. Pertaining to the blood system.
Haller's organ. A sense organ on the anterior pair of legs in certain ticks.
Head. The anterior body-division of the higher animals.
Heart. A muscular tubular or saccular organ which propels the blood through the arteries.
Hectocotylus arm. One of the arms in the male in many cephalopods used to transfer sperm to the female.
Hermaphroditic. Having the two sexes united in one animal.
Hinge ligament. The flexible portion of a bivalve shell which joins the two valves.
Homologous. Having had a similar origin.
Host. The animal which harbors a parasite.
Hydranth. An individual feeding-polyp in a hydroid colony.
Hydrocladium. Small branches in the Plumulariidae bearing the polyps.
Hydrocaulus. The stem of a hydroid colony.
Hydroid. The sessile, asexual generation of the Hydromedusae and Scyphomedusae.
Hydrorhiza. The root-like projection of a hydroid colony by which it is attached.
Hypodermis. The cellular layer which forms the inner portion of the integument of most invertebrates and secretes the cuticula.
Hypophysis. A ventral projection of the brain in vertebrates.
Hypopus. The youthful form of certain mites.
Hypostome. The projection of a hydroid's body which bears the mouth.

Infrabasals. Calcareous plates between the basals in certain crinoids.
Infundibulum. A longitudinal fold of the pharyngeal wall of ascidians.
Insertion plate. The portions of the shell of chitons beneath the girdle.
Integument. The outer covering of an animal; in most invertebrates it consists of an outer cuticula and an inner hypodermis.
Interlamellar partitions. Vertical walls which join the two lamellae of a pelecypod's gill.
Intermediate host. The animal which harbors the larval form only of a parasite.

Interray. One of the divisions of the radiate body of echinoderms.
Intestine. The division of the digestive tract in which absorption goes on.
Introvert. The anterior part of a sipunculid, which can be invaginated.

Keber's organ. An excretory organ in pelecypods.
Kidney. An excretory organ.

Labium. The under lip of many arthropods.
Lamella. A leaf- or plate-like structure.
Larva. A young animal which has left the egg and is leading a free life, but which has not yet completed its development.
Lateral. A position to the right or left of the median line.
Lateral teeth. In the radula of mollusks the teeth on each side of the centrals; in pelecypods the hinge-teeth either anterior or posterior to the cardinals.
Ligament. The elastic band joining the two valves of a pelecypod's shell.
Lip. The margin of the aperture of a snail shell.
Lithocyst. A marginal sense-organ in campanularian medusae.
Liver. A digestive gland.
Lophophore. A circular or horseshoe-shaped ridge bearing tentacles in Bryozoa, Brachiopoda and Phoronidea.
Lorica. The shell enclosing the body in many rotifers.
Lumen. The cavity within a tubular organ.
Lunule. A depressed area in front of the umbo in certain pelecypods.
Lycophore. The ten-hooked embryo of the Cestodaria.

Macronucleus. The large nucleus of an infusorian.
Madreporite. The porous plate through which fluids enter the ambulacral system.
Malpighian tubes. The kidney of insects and many arachnids.
Mammary organ. An elevation in the vestibule of certain entoproct bryozoans which nourishes the embryos.
Mandible. The anterior pair of mouth-parts in arthropods.
Mantle. The integumental fold in mollusks and brachiopods which secretes the shell; the body-wall of ascidians beneath the tunic.
Manubrium. The projection of a medusa's body which bears the mouth.
Marginal teeth. In the radula of mollusks the teeth at the side of the laterals.
Mastax. The muscular pharynx of a rotifer.
Maxilla. The paired mouth-parts immediately behind the mandibles in arthropods.
Maxillipeds. The anterior thoracic appendages in crustaceans and centipeds.
Medusa. A free-swimming jelly-fish.
Medusoid. The sexual generation of the Hydromedusae and Scyphomedusae.
Megascleres. The larger spicules in sponges which form the principal skeletal support.
Mesentery. A lamella which supports some one of the viscera; in Scyphozoa and Anthozoa a lamella extending from the body-wall into the gastrovascular space.
Mesoglea. The middle tissue between the ectoderm and entoderm in Coelenterata.
Metacnemes. The secondary mesenteries of Anthozoa.
Metamere. One of the serial, homologous body-segments, together with its appendages, which form the body of an articulate animal.
Metapodium. The hinder part of the molluscan foot.
Metasoma. The primitive segmented trunk of an articulate animal.
Metastomium. The posterior portion of the head of an annelid.

Metazoa. The division of the animal kingdom comprising the many-celled animals.
Micronucleus. The smaller of the nuclear bodies in infusorians.
Microscleres. The minute spicules in sponges.
Miracidium. The youngest larval stage of trematodes.
Monœcious. Having the two sexes united in one individual.
Mother-of-pearl. The inner layer of the shell of mollusks.
Moult. To shed the cuticula or the outer portion of it.
Mouth-parts. The masticatory appendages on the head of arthropods.

Nauplius. A young larval form of many crustaceans, especially entomostracans.
Nematocyst. The stinging organ in the Cnidaria which is within the cnidoblast.
Nephridium. A urinary tubule in annelids.
Nephrostome. The ciliated opening of a nephridium into the body-cavity.
Nerve commissure. A nerve connecting the two members of a pair of ganglia.
Nerve connective. A nerve connecting two ganglia not of the same pair.
Nettle cell. The stinging organ or nematocyst in the Cnidaria.
Neuropodium. The ventral division of the parapodium of an annelid.
Nidamental glands. The large glands which secrete the egg-capsules in the squid.
Notochord. A cylindrical rod formed in the young embryo along the mid-dorsal line of the digestive tube and ventral to the nervous system in chordates.
Notopodium. The dorsal division of the parapodium of an annelid.
Nucleus. A spheroidal body in a cell, the center of its activities.

Ocellus. A minute primitive eye in arthropods.
Œsophagus. The gullet, the division of the digestive canal leading from the pharynx to the stomach.
Ommatidium. A single element of the compound eye of an arthropod.
Onchosphere. The six-hooked embryo of tapeworms.
Operculum. A plate closing an opening or covering some other structure.
Oœcium. A structure in Bryozoa in which the embryo develops.
Oral. The side of the body containing the mouth in a radiate animal.
Oral groove. A groove leading to the mouth in ciliate infusorians.
Organs of Cuvier. Glandular tubes extending from the rectum in holothurians.
Organ of Keber. An excretory organ in pelecypods.
Orthoneurous gastropods. Snails in which the pleuro-visceral nerve connectives are not crossed.
Osculum. The cloacal opening in sponges.
Ossicles. The calcareous plates in the body-wall of echinoderms.
Otocyst. An organ of hearing.
Otoporpae. Thickenings of the ectoderm at the lithocysts in Narcomedusae.
Outer lip. The portion of the lip of the aperture of a snail shell away from the axis.
Ovary. The female sexual gland.
Ovicell. A brood-chamber or oœcium in bryozoans.
Oviduct. The tube leading from the ovary towards the outside.
Ovipositor. The organ by means of which certain arthropods deposit their eggs.
Ovum. The female sexual cell, the egg.

Pallets. Small calcareous plates in the siphons of Teredo.
Pallial line. The line along which the margin of the mantle is attached to the shell in pelecypods.
Pallial sinus. The indentation in the pallial line, caused by the insertion of the siphonal retractor muscle.
Palp. A sensory organ near the mouth.

Pancreas. A digestive gland in the squid.
Papulae. Delicate projections of the body-wall in the starfish.
Paramylum. A granular substance resembling starch in Euglena.
Parapodium. The appendage of annelids.
Parasite. An animal which lives in or on another and feeds upon its nutritive fluids.
Parenchyma. A vesicular connective tissue which fills the body-cavity of flatworms and leeches.
Parietal lip. The side of the aperture of a snail shell towards the axis.
Parietal tooth. A tooth on the parietal lip.
Parthenogenesis. Reproduction by means of unfertilized eggs.
Paxillae. Calcareous rods surmounted by minute spines on the aboral surface of certain starfish.
Pedicellariae. Minute pincer-like organs present on the external surface of certain echinoderms.
Pedipalps. The second pair of appendages in arachinids.
Peduncle. The stalk by which a sessile animal or a sessile organ is attached.
Pen. The shell of the squid.
Pericardium. The membrane surrounding the heart.
Periopods. The thoracic appendages posterior to the maxillipeds in crustaceans.
Periostracum. The outer layer of the molluscan shell.
Periphery. The outer surface of a body.
Periproct. The region immediately around the anus.
Perisarc. The cuticular outer covering of a hydroid.
Peristome. A membrane surrounding the mouth in echinoderms; the outer lip of the aperture of a snail shell.
Peristomial gills. Gills on the peristome of sea-urchins.
Peristomium. The posterior portion of the head in most annelids.
Peritoneum. The membrane lining the body-cavity.
Peritreme. The stigmal plate in certain mites.
Peronia. Thickenings of the ectoderm at the base of the tentacles in Narcomedusae.
Petaloid area. The petal-like arrangement of the aboral ambulacral pores in certain sea-urchins.
Pharynx. The division of the alimentary tract immediately back of the mouth.
Phragmocone. The chambered portion of the cephalopod shell.
Pinnules. The small branches of the arms of crinoids.
Plankton. A collective term referring to all small forms of life in the surface waters of the sea or fresh water.
Planula. The ciliated free-swimming larva of many Cnidaria.
Pleopod. An abdominal appendage in crustaceans.
Plerocercoid. A tapeworm larva resembling the scolex of the adult worm.
Plerocercus. A tapeworm larva consisting of the scolex and some of the proglottids.
Pleurobranch. A gill attached to the body-wall in crustaceans.
Pluteus. The larva of a sea-urchin or a brittle star.
Podia. The ambulacral appendages of echinoderms.
Polian vesicle. A sac projecting from the ring canal of echinoderms.
Polymophism. The condition in which an animal species exists in several distinct forms.
Polyp. A sessile individual in Cnidaria or Bryozoa.
Posterior. At or towards the hinder end of an animal.
Proboscis. A prehensile organ in certain worms, usually a portion of the pharynx; the beak-like mouth-parts of certain arthropods.
Proglottid. A tapeworm segment.

Proöstracon. The grooved or trough-like shell of certain cephalopods.
Propodium. The anterior portion of the molluscan foot.
Prosoma. The primitive head of annelids.
Prostate gland. The gland which secretes the fluid in which the spermatozoa are suspended.
Prostomium. The anterior portion of the head of annelids.
Protopodite. The basal segment of a crustacean's leg.
Protractor muscle. A muscle which extends the organ to which it is attached.
Proximal. The position of a part of an organ towards the point of attachment —opposed to distal.
Pseudopodium. A retractile locomotory process in sarcodins.
Pseudoscolex. The anterior end of certain tapeworms which lack a scolex.
Pseudostigmatic organs. A pair of club-shaped bristles on oribatid mites.
Pulsating vacuole. A globule of excretory fluid in many protozoans.
Pyrenoids. Deeply staining bodies in the chromatophores of Euglena.

Rachis. The upper portion of the Pennatulacea, containing the polyps.
Radial symmetry. Having the parts or organs arranged symmetrically about a common center.
Radials. Calcareous plates in crinoids above the basals.
Radius. One of the rays, the five main divisions of the echinoderm body.
Radula. The band of calcareous teeth in the pharynx of most mollusks.
Ray. One of the main divisions of the radiate body of echinoderms.
Receptaculum seminis. A receptacle for sperm in the female animal.
Rectum. The posterior division of the digestive tract.
Respiratory tree. The paired branched diverticula of the rectum of holothurians.
Retractor muscles. Muscles which draw an organ towards its point of attachment.
Rhinophores. The posterior pair of tentacles in many opisthobranchs.
Rhopalia. The sense organs or tentaculocysts of scyphomedusans.
Ring canal. The central portion of the ambulacral system in echinoderms.
Rostellum. A projection of the scolex of many tapeworms bearing hooks.
Rostrum. A projection of the carapace in crustaceans; the cylindrical terminal portion of a belamnite shell.

Salivary glands. Digestive glands at the anterior end of the digestive tract.
Scleroblasts. The cells of the mesoglea of sponges which secrete the spicules.
Scolex. The anterior end of a tapeworm containing the organs of attachment.
Scutum. A shield on the dorsal surface of ticks.
Scyphistoma. The hydroid generation of the Scyphomedusae.
Secondary flagellum. A small branch of the tentacle in certain crustaceans.
Segment. One of a number of serial divisions of an animal's body or of an organ.
Septum. A plate forming a division wall between two spaces; one of the radial calcareous plates of a stony coral.
Sessile. Fixed to one place, without locomotory powers—of an animal; not on a stalk or stem—of an organ.
Seta. A bristle.
Sexual. Reproduction through the agency of the two sexes.
Siphon. The organ through which water enters or leaves the mantle cavity in mollusks and ascidians.
Siphonal canal. A tubular prolongation of the lip of the aperture of many snail shells to enclose the siphon.
Siphonoglyph. A ciliated groove at one end of the mouth in the Anthozoa.

Siphonozooid. Rudimentary zooids through which water flows into the entodermal canals in the Pennatulacea.
Siphuncle. The tubular portion of a nautilus' body which extends through the chambers.
Somite. One of the serial, homologous body-segments which form the body of an articulate animal.
Spermatheca. A sac for the storing of sperm in the female animal, a seminal receptacle.
Spermatophore. A capsule or mass of spermatozoa.
Spermatozoön. The male sexual cell.
Sperm-duct. The vas deferens.
Sperm-sac. A sac for the storing of sperm in the male animal, a seminal vesicle.
Spicule. A minute calcareous or silicious body in sponges and echinoderms.
Spinnerets. Appendages at the hinder end of a spider containing the openings of the silk glands.
Spiracle. An external opening in the tracheal system in arthropods.
Spire. The portion of a snail shell above the large lowest whorl.
Spongin. The substance composing the elastic fibers of a sponge.
Spongioblasts. The mesoglea cells which form the elastic fibers of a sponge.
Sporont. The sporulating stage of a sporozoan.
Sporosac. A sessile medusoid, one which remains attached to the parent hydroid.
Statoblast. Disc-like buds in fresh-water Bryozoa which live through the winter.
Sternum. The ventral portion of the cepholothorax surrounded by the legs in spiders.
Stigmal plate. A plate surrounding the spiracle in certain mites.
Stigmata. The respiratory openings in the pharyngeal wall in ascidians.
Stomach. A division of the digestive tract in which digestion goes on.
Stomach pouch. A diverticulum of the stomach.
Stone canal. A tube joining the madreporite with the ring canal in echinoderms.
Streptoneurous gastropods. Snails in which the pleuro-visceral connections cross each other.
Strobilation. The process of terminal budding.
Stylets. Calcareous needles in the proboscis of hoplonemerteans.
Subchelate. A pinching claw formed by the bending of the terminal segment over the next one.
Subcuticula. The tissue beneath the cuticula in trematodes and cestodes.
Subgenital pocket. A pocket in the subumbrella of many scyphomedusans.
Subneural gland. A glandular body in ascidians.
Subumbrella. The oral surface of a medusa.
Summer eggs. Thin-shelled eggs produced by parthenogenetic females of certain crustaceans, usually in the summer.
Supporting layer. The non-cellular layer between the ectoderm and entoderm in Hydrozoa.
Swimmeret. The abdominal appendage of a crustacean, a pleopod.
Symbiotic. The living together of two dissimilar organisms, each being dependent upon the other.
Systemic heart. The median heart of the squid.

Tactile. Relating to the sense of touch.
Tarsus. The segmented foot of an arthropod.
Telson. The terminal segment of a crustacean or arachnoid.
Tentacle. An elongated tactile organ.

Tentaculocyst. The sense organs of the Scyphozoa.
Terminal. Towards or at the posterior or the distal end.
Test. The tunic of the ascidian; the rigid shell of the sea-urchin.
Testis. The male sexual gland.
Theca. The outer wall of the calcareous cup of a stony coral.
Thorax. The body-division just anterior to the abdomen.
Tiedemann's vesicles. Minute diverticula of the ring canal of the starfish.
Tooth papillae. Projections from the jaw of a brittle star.
Trachea. A respiratory tube in air-breathing arthropods.
Trichocyst. A cyst containing a defensive bristle in the ectosarc of infusorians.
Trochophore. A larval form common to annelids, mollusks, and other animals.
Trophi. The paired jaws in the mastax of rotifers.
Trophosome. The hydroid stage of hydromedusans.
Trophozooid. The youthful stage of a fungoid coral.
Tunic. The outer cuticular covering of tunicates.

Umbilicus. A depression or cavity at the axial base of a snail shell.
Umbo. The protuberance above the hinge on the shell of a pelecypod.
Ureter. A tube forming the outlet of the kidney.
Uropod. The sixth swimmeret of certain crustaceans which forms the swimming tail.
Uterus. A dilated portion of the oviduct in which the egg or the developing animal may be held.

Vagina. The terminal division of the female reproductive tract.
Vas deferens. A duct leading from the testis towards the external opening; the sperm-duct.
Vegative organs. Those organs which have to do with the processes of nutrition, growth, and the expulsion of wastes.
Vein. A vessel which brings blood towards the heart.
Velarium. The false velum of Cubomedusae.
Veliger larva. The larva of many gastropods.
Velum. The circular muscular locomotory membrane of a hydromedusan.
Ventral. On or towards the underside of an animal.
Ventricle. A chamber of the heart from which blood is sent over the body.
Vesicula seminalis. A sperm-sac in the male animal.
Vestibule. The depression within the lophophore in entoproct bryzoans.
Vibraculum. Whip-like defensive organs in many bryozoans.
Viscera. The organs within the body-cavities.
Visceral mass. The compact group of organs comprising the principal viscera in mollusks.

Winter eggs. Thick-shelled eggs produced by parthenogenetic females after fertilization, usually in the fall.

Zoöchlorellae. Single-celled algae which live symbiotically with some invertebrates.
Zoœcium. The outer cuticular covering of a bryozoan.

INDEX

This Index includes the names of species, genera and all other systematic groups, and also the names of anatomical structures. Specific names begin with a small letter and each is followed by the name of its genus in parentheses. All other names and terms begin with capital letters. Specific and generic names which appear in italics are synonyms.

In the case of an anatomical structure the page referred to is the one on which a definition or description of the structure will be found.

In the case of a species, genus, or other systematic group the page referred to is the one on which the principal description of it will be found.

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